With the Government Geologist's Compliments.

WESTERN AUSTRALIA.

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1st no of 1905

GEOLOGICAL SURVEY.

BULLETIN No. 18.

I.—Geological Features and Auriferous Deposits

OF

MOUNT MORGANS
(Mount Margaret Goldfield);

ALSO

II.—Notes on the Geology and Ore Deposits

OF

MULGABBIE
(North Coolgardie Goldfield),

BY

C. F. V. JACKSON,
ASSISTANT GOVERNMENT GEOLOGIST.

Issued under the authority of the Hon. R. Hastie, M.L.A., Minister for Mines.

WITH TWO MAPS AND SHEET OF SECTIONS.

PERTH:
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Photo.: C. F. V. JACKSON.

The Morgans Lodes.

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PREFATORY NOTE.

THIS Bulletin contains two reports from the pen of Mr. C. F. V. Jackson, the first on the Geological Features and Auriferous Deposits of Mount Morgans, in the Mount Margaret Goldfield, and the second upon the Geology and Ore Deposits of Mulgabbie, in the North Coolgardie Goldfield.

That portion of the Mount Morgans Field described by Mr. Jackson comprises an area of about 30 square miles. There are very strong grounds for believing that the district embraces the north-western extension of that belt of auriferous rocks which includes Edjudina and Yundamindera, a description of which is given in a former Bulletin, No. 11.

The staple formation of Mount Morgans comprises a complex of basic and acidic rocks of the geological age of which the district affords no direct evidence, though in all probability it forms part of the same series as that so largely developed in other portions of the Eastern Goldfields, and invariably assumed to be Archæan. The ubiquitous cover of superficial deposits rendered geological mapping somewhat difficult, but, as far as possible, the different rock masses and associated ore deposits have been followed and delineated upon the plan with which the report is accompanied.

The basic rocks, the "greenstones," are essentially hornblendic, and although they present many varieties, have all been distinguished by one single colour and symbol on the Geological Map. Some of the basic rocks have been converted into schists, which are chiefly developed along the junction between the former and the acidic rocks.

The acidic rocks, which occupy the greater portion of the area to the east of what may be called the Mount Morgans ridge, appear principally to be quartz and felspar-porphyries, which from the evidence accumulated seem to be intrusive into the greenstones.

Portions of the porphyries have been subject to mechanical deformation, and converted into rocks which may for convenience be best described by the term granitic schists.

The exigencies of the Department prevented any detailed petrographical work in connection with the Mount Morgans rocks being carried out up to the time the report was written.

The ore deposits of Mount Morgans, according to Mr. Jackson's observations, are of two distinct types, viz. :—

(*a*.) The banded quartz reefs and lodes, of a type identical with those which form such conspicuous features in the other goldfields of the State; and

(*b*.) The normal quartz veins.

The banded quartz veins form a series of bold outcrops on the summit of the main Mount Morgans ridge, and have been traced across country for a distance of about four miles, along a powerful line or lines of weakness, which have formed channels for the more or less free circulation of mineral-bearing solutions. These banded quartz veins vary very much in size; and, owing to their irregularity, are naturally difficult to work. The plan, upon the scale of 160 feet to the inch, of the veins at the 100-foot level, in the Westralia Mount Morgans, Guests, Lily of the Valley South, and the Millionaire Mines, accompanying the report, graphically depicts the irregularity of the deposits, and should serve a very useful purpose.

So far as any observations have been made, it appears that the ore-chutes have a marked dip to the south.

The report is accompanied by a schedule of gold returns, prepared from official statistics, which demonstrate that, from the area embraced by Mr. Jackson's work, there have been raised 215,564·32ozs. of gold from the crushing of 217,551·00 tons of quartz, giving an average of ·99oz. to the ton. Of this amount the banded quartz reefs have been responsible for 211,315·80ozs., obtained from the milling of 215,534 tons of ore, and the normal quartz reefs for 4,248·52ozs., resulting from the treatment of 2,017·00 tons of quartz. These figures show that the banded quartz reefs of what may be called the main ore channel have returned an average of ·98oz. per ton, whilst the normal reefs have reached 2·10ozs. per ton.

The horizontal extent of the deposits, so far as at present mapped, would seem to assure the future of the district as an ore-producer; and, as the lodes owe their origin to deep-seated agencies, they may be expected to persist to any depths to which mining operations are likely to follow them; the fact, however, cannot be ignored, that deposits of the nature of those described are extremely irregular.

The second report of Mr. Jackson describes the occurrence of the telluride of gold and silver "petzite" at Mulgabbie. From Mr. Jackson's observations it appears that the discovery of telluride ores in the locality has not materially affected the conditions of mining, although the find warrants rather more thorough investigation than has hitherto been given to it. Mr. Jackson points out the difficulty the unaided prospector experiences, under the prevailing conditions, in making much headway, when the only treatment plant available is a small three-head mill, at which the crushing charges amount to £2 per ton.

A. GIBB MAITLAND,

Government Geologist.

Geological Survey Office,

Perth, 13th December, 1904.

AUTHOR'S PREFACE.

THE centre of interest in the following report is the Geology of the Mount Morgans lodes, particularly those which constitute the ore bodies of the Westralia Mount Morgans mine.

Owing to their irregularity, the deposits are not only difficult to mine, but their exact disposition would be difficult to grasp without the aid of well-kept plans.

Indebtedness must here be recorded to Mr. Harold Gladstone, mine surveyor, for co-operation and assistance in that part of the work depending on the mine plans; and, at the same time, thanks are tendered to Mr. Percy Morgans, Mr. Marmion, and the officials connected with the mine.

C. F. V. JACKSON,

Assistant Geologist.

2nd November, 1904.

I.

GEOLOGICAL FEATURES AND AURIFEROUS DEPOSITS

OF

MOUNT MORGANS

(MT. MARGARET GOLDFIELD).

Introduction.

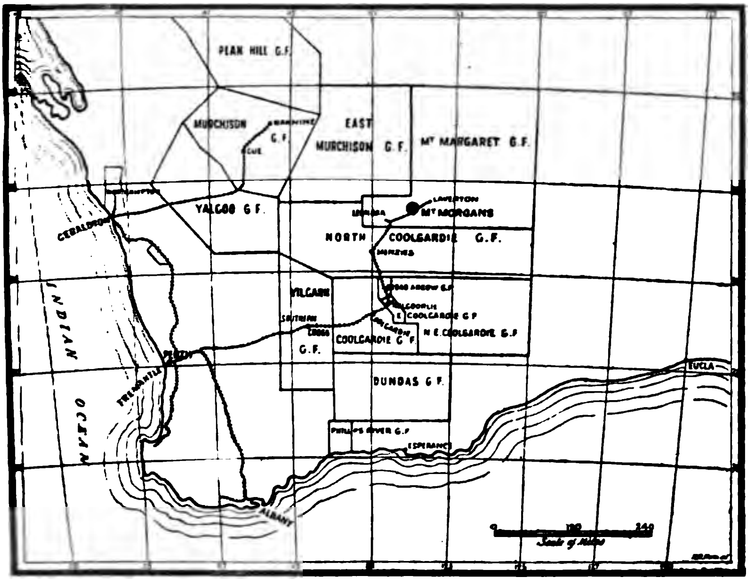

Fig. 1.—Locality Map.

The Mount Margaret Goldfield was declared by proclamation gazetted on the 12th of March, 1897, to take effect from the 1st of April of that year: its boundaries were amended by proclamation gazetted on the 28th of March, 1902, taking effect on the 2nd of April, 1902, so as to embrace an area of 42,252 square miles.

Its boundaries as defined by the authorities are as follow:—

"Bounded by lines starting from a spot about 15 miles east and about 13 miles north from the summit of Mount Ida, and extending north about 35½ miles; thence east about 67½ miles, passing through a tree marked 'A.N. 33' at Doyle's Well; thence north about 14 miles; thence east about 7 miles; thence north to the 26th parallel of south latitude; thence east to the 125th meridian east longitude; thence south to a spot due east of a

tree marked 'B 82' at Brickey's Soak; thence west through the said tree to the starting point. Excluding all townsites and fee simple lands within the boundaries."

The field, for administrative purposes, is divided into three main districts, Morgans (the official centre), Malcolm (including Leonora), and Laverton. The production of each of these districts during 1903 is officially stated as follows:—

	ozs.
Morgans	71,798·78
Malcolm (including Leonora)	93,962·99
Laverton	46,728·83

The total production of the Mount Margaret Goldfield up to the end of 1903 is shown by the following tabulated statement:—

Production of the Mount Margaret Goldfield.

	ozs.	£ *
Previous to 1897	4,992·10	18,471
1897	22,592·09	83,591
1898	49,717·77	183,956
1899	79,923·72	295,718
1900	145,688·75	539,048
1901	190,032·15	703,119
1902	211,308·77	781,842
1903	212,490·60	786,215
Total	**916,745·95**	**3,391,960**

* Value of gold assumed, £3·70 per oz.

Besides the production of gold, the Mount Margaret Goldfield has contributed a good deal towards the copper production of the State.

Mount Morgans District.

History.

The creation of the Mount Morgans District as a separate official centre of the Mount Margaret Goldfield dates only from the year 1902. The gold production however is recorded in the official statistics from 1897 to 1903 as under:—

Year.	Ore treated.	Gold therefrom.	Rate per ton.
	tons.	ozs.	ozs.
1897	4·00	6·00	1·50
1898	1,796·00	2,175·28	1·21
1899	5,562·00	13,710·60	2·46
1900	25,003·00	32,044·41	1·28
1901	36,012·00	42,697·64	1·18
1902	56,367·50	56,432·50	1·00
1903	93,526·75	69,081·52	·73
Total	**218,271·25**	**216,147·95**	**·99**

Mount Morgans is situated 367 miles to the east, and 220 miles to the north of Perth, being accessible by a branch railway which joins the main line at Mount Malcolm.

In Bulletin No. 13 of the Geological Survey of Western Australia, dealing with the Geology and Auriferous Deposits of Leonora, there appears (pp. 7 to 10), as well as a short account of the progress of the Mount Margaret Field, a brief outline of its geographical history, which dates from the Exploratory Expedition of Sir John Forrest in 1869. Sir John Forrest's track to Lake Carey on that expedition passed some miles to the south of the actual locality now known as Mount Morgans.

In 1894, Mr. Göczel visited Lake Carey, and as he mentions the ridge on which Mount Morgans is situated it seems probable that he traversed the locality.

Authentic records of the district, however, practically begin with its mineral production and date from the pegging of the lease now known as the Westralia Mount Morgans (No. 4297) in June, 1896.

The Warden of the Mount Margaret Goldfield, in his report for 1898, states that business and residence areas were about to be laid out at Morgans, and there were in that year 16 leases held in the vicinity of and adjoining the Westralia Mt. Morgans mine. In the report for 1897 mention is made of a Tremaine Mill having been erected for the purpose of testing the Westralia Lode, and considerable prominence is given in the report for 1899 to the Mount Morgans district generally. These reports further state during 1900 that a 20-stamp mill ran at the Westralia Mt. Morgans and thirty additional stamps were being erected, also that other properties in the vicinity gave promise of developing.

Since then the development of the one large mine and a few adjoining and neighbouring leases has been almost entirely responsible for the growth of the district, *i.e.*, the area comprised by the accompanying Geological Map (30 square miles).

The map is bounded by an east-and-west line four miles north of the township of Morgans, and a similar parallel two miles to the south; on the east and west by meridian lines three miles and two miles from the township respectively.

Physiography.

The township of Morgans is situated on the western side of a ridge of somewhat broken outline, which extends to the north-west and south-east for a distance of five miles.

At the north-west extremity is situated Mount McKenzie, the highest point, some 220 feet above the mean surface level. To the south-east of the township, the ridge terminates, and the rocks are covered by recent superficial accumulations forming wide flats which extend to the margin of the Lake Carey saltmarsh. In an east-south-east direction, some eight miles from Mount

Morgans, another ridge, of which Mount Margaret is the highest point, appears on the northern margin of the saltmarsh. Between the ridges the flatness of the country is only broken here and there by small isolated hills of greenstone.

The altitude of Morgans above sea level is but little different from the average level of the Eastern Goldfields, and is approximately 1,450 feet. The average annual rainfall from the records of five years is 9·24 inches.

The district is relatively well provided with water obtained from wells; the supply pumped from two wells for the Westralia Mount Morgans and Guest's mines being sufficiently large to also supply the town.

Geology.

The western side of the area embraced by the accompanying Geological Map is occupied by a series of Basic Rocks, greenstones and schistose derivatives; while the eastern side is occupied chiefly by an intrusive granitic rock—a porphyry; the main ridge with a north-westerly and south-easterly axis along which the principal lodes have been developed approximately marking the junction of the two formations.

A very large portion of the area is covered by recent superficial and alluvial deposits, not only on the flats but, to a great extent, on the slopes of the hills which except near the apex are not very steep and the talus has accumulated to a considerable thickness, in many places being cemented into a compact mass. A good deal of the detail along the junction of the two formations is thus obscured.

In point of geological age, the Basic Rocks no doubt belong to the same geological series as those outcropping elsewhere on the Eastern Goldfields and form a portion of the area of palæozoic greenstones often referred to as "the Second Auriferous Belt."*

With regard to the granite or porphyry, there is no evidence with regard to age other than that it is intrusive into the greenstones.

Superficial Accumulations.

The recent deposit covering the greater part of the surface in the district is chiefly the usual sandy soil resulting from the degradation of the underlying rocks, and except towards the south-east in the vicinity of Lake Carey does not in general attain a greater thickness than a few feet.

On the gentle slopes of the main ridge a thick covering of talus has accumulated, which in many places has become cemented into a compact mass by the solution and redeposition of the lime contained in the finer material.

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* Mining Handbook to the Colony of Western Australia, by H. P. Woodward, pp. 36 and 37. Perth: By Authority, 1895.

Photo.: C. F. V. JACKSON.

Weathering of Basic Rocks and Formation of Ironstone.

There is also the thin stratum of earthy limestone or "cement" intervening between the superficial accumulations and the rock masses beneath, which is similar to that described in a report on the Leonora district.*

Similar deposits also of Ironstone (Laterite) occur, the high level and low level forms being both recognisable, but it has not been found possible to distinguish them separately on the map. The chief point of difference between them seems to be in the formation of the former contemporaneously with the decomposition of the rock beneath (Plate I.) from which the iron is derived, and trails of the original rock structure can be observed in the less ferruginous portions of the base.

In the case of the low level variety a complete disintegration of the rocks appears to have first taken place, and the formation of the Laterite subsequently gone on in the accumulated loose ferruginous material thus produced.

As a source of gold these superficial deposits have taken very little part in the production of the district, the small areas where they have proved auriferous being shown on the map.

Greenstones.

It is in association with these rocks, essentially hornblendic rocks, that the auriferous deposits mainly occur. The greenstones chiefly occupy the western portion of the area shown on the map, but are found in more or less isolated patches in the granitic area to the east.

The more important deposits are at or near the junction of the two formations or in the vicinity of the numerous dykes of which the areas of greenstone on the eastern side are everywhere intersected.

Owing to the cover of superficial deposits it has not been found possible in more than a few instances to indicate the course of these dykes.

The greenstones have been distinguished on the Geological Map of the district by a single colour, and though possibly the area thus delineated contains more than one variety of Basic or ultra-Basic rock, no more than structural distinctions can be observed, a coarse-grained, a fine-grained, and schistose variety being most prominent.

The areas occupied by each are not sufficiently well-defined for separate mapping, but generally speaking the former are chiefly

* Geology and Auriferous Deposits of Leonora. Geological Survey of Western Australia, Bulletin No. 13, p. 16. Perth: By Authority, 1904.

confined to the western portion of the area, while the fine-grained variety is found on both sides. The schists, as might be expected, are most prominent along the main junction of the two formations: they occupy roughly a strip along the western side of the zone of contact.

In the hand specimen the ferro-magnesian mineral of the coarse-grained rock has a somewhat acicular appearance. A section of a specimen [5674] seen under the microscope shows it to have been essentially a hornblende-felspar rock, the hornblende having become much decomposed, and there is a considerable quantity of ilmenite with leucoxene present. The section shows a little quartz, and the original rock was probably somewhat of the nature of a basic diorite. The fine-grained variety in the hand specimen is compact and heavy, a section of a specimen [5676] showing under the microscope, with the exception of the more minute structure, similar features to the coarse-grained rock.

The macroscopic and microscopic characteristics of the schists are similar to those of the greenstone schists elsewhere.

Porphyry.

This rock occupies the greater portion of the area to the east of the main ridge, and appears on the west in the form of narrow dykes.

A massive and crushed variety are roughly distinguishable, but under the microscope sections of specimens [5680], [5666], [5665] are, with the exception of differences in degree of foliation, practically identical. The ferro-magnesian mineral is a white mica, and phenocrysts of quartz and triclinic felspar occur in the ground mass. The rock is a quartz-felspar porphyry, and the main mass assumes a light-brown colour on weathering.

Distribution and Character of the Ore Deposits.

The ore deposits may be separated into two main divisions:—

(*a*.) Lodes which are genetically similar to the banded and hematite-bearing quartz lodes which are a typical feature of the Mt. Margaret and Murchison Goldfields; and

(*b*.) Gold-bearing veins of quartz of ordinary type in greenstone.

The former occur along the axis of the main ridge in a series of bold outcrops. (Pláte 2.) The apex of the ridge thus formed is a prominent feature of the landscape, locally named "The Morgans Line." (*See* Frontispiece.)

The latter—the gold-bearing quartz veins—occur almost entirely in the smaller areas of greenstone to the east of the main dividing ridge.

Photo: C. F. V. JACKSON.

Photo. : C. F. V. JACKSON.

Westralia Mount Morgans Mine and Reduction Plant.

The Mines:

The Westralia Mount Morgans.

Year.	Ore treated.	Gold therefrom.	Rate per ton.
	tons.	ozs.	ozs.
1897	4·00	6·00	1·50
1898	1,726·00	2,040·18	1·18
1899	5,532·00	13,669·15	2·49
1900	17,283·00	25,868·35	1·49
1901	24,168·00	37,363·80	1·54
1902	56,022·00	55,982·75	·99
1903	86,780·00	64,945·85	·74
Total	**191,515·00**	**199,876·08**	**1·04**

The leases are situated on the main ridge near the eastern boundary of the township, lease No. 4,297 being that which includes the outcrop of the Westralia Mount Morgans lodes.

The original prospector who pegged the lease on the 1st of June, 1896, was H. Lilley, the registration being made at Menzies. An option was taken almost immediately by Mr. A. E. Morgans, and development of the property has since steadily proceeded.

The deposit is by far the most important of any in the district. Apart from its size and irregular nature, it has many points of interest, not the least being its similarity of origin to the banded and hematite-bearing quartz lodes which have already been referred to, and which though elsewhere frequently associated with auriferous deposits are not themselves generally highly gold-bearing. Their occurrence is described in Bulletin 16, page 25, on the Murchison Goldfield, where "they extend as roughly parallel bars, often continuous for many miles in length: they are generally from two to four chains in width, and outcrop in the form of rough serrated ridges. These bands are merely quartz reefs or lodes of a peculiar type, and vary in composition from almost pure quartz through varieties of banded jaspers, often of great beauty, to practically pure banded hematite." At Boogardie,* on the Murchison Goldfield, the formation of this banded quartz is stated to occur "in old fault lines or joints, along which zones of weakness thermal solutions, containing silica, iron, etc., have forced their way to the surface, and gradually converted the original highly foliated rock into its present form."

At Mt. Morgans conditions have been highly favourable along the contact of the intrusive mass of porphyry for the formation of such areas of highly crushed and foliated rock, and the production of zones of weakness in which the lode-forming processes have taken place. (Plate 7, fig. 3.)

* Lennonville, Mt. Magnet, and Boogardie. Bulletin of the Geological Survey of Western Australia, No. 8, pp. 16, 17, C. G. Gibson. Perth: By Authority, 1903.

The quartz lodes of Morgans are in most cases more or less banded in appearance in the oxidised portions, but the typical banded hematite variety is not represented, and though they have been formed most frequently associated with the basic rocks, they are also found entirely in the porphyry. Their chief morphological characteristic, independent of the habit of the shoots of ore within them, is that of a solid body or pipe of lens section, the main axis of which trends or dips to the south at an average angle of about 45 degrees. Thus the ore bodies shown in the section at the main shaft (Plate 7, Fig. 2) are no doubt those which were worked in the large open cut some three or four chains to the north of the shaft (Plate 4).

The ore shoots have also a southerly trend, and the deposit, owing to its irregularity, has been difficult to work.

Two lodes have been chiefly worked, known as the main lode and eastern lode (*vide* Plate 7, Fig. 2), and these have been fairly continuous within the workings, but their extension south is more difficult to follow, and numerous breaks occur.

The lodes in the adjoining lease to the south (the Guest) appear to be directly related to the Westralia main and east lodes, *i.e.*, formed in the same line of fault or weakness, but they are not—the main lode at least—directly connected.

The shoots of ore in both lodes have had a marked trend to the south, and the Company were fortunately able to purchase the Guest lease and extend their workings southwards.

The deposit is worked by a vertical shaft and, so far, six main levels. In the two upper levels the lodes were almost vertical or with a tendency to a westerly dip, but in the lower levels there has been an average dip to the east of 55 degrees.

The ore from the unoxidised portion of the lodes, when examined by the Acting Mineralogist and Assayer, was found to consist of "hard flinty quartz, dark greyish to black in colour, heavily charged with iron pyrites, and carrying in addition small quantities of chlorite and calcite, the latter occurring principally in the form of small veins throughout the stone."

The average output of the mine is about 7,000 tons* per month, which is dealt with by a 60-stamp crushing mill with a duty of 4·4* long tons per stamp. The product contains 4,600* tons of sands with an average of 17* per cent. to 20 per cent. of sulphides and 2,400* tons of slimes with an average of 9* per cent. of sulphides. The pulp from the battery passes to an air lift, thence through pipes and Butter's Distributers to collecting tanks of 190* tons capacity; the slimes overflowing through slab gates to spitzkasten which return sands to main air lift. The slimes from

* Figures supplied by Metallurgist, April, 1904.

Photo.: C. F. V. JACKSON.

Main Open Cut, Westralia Mount Morgans.

Photo.: C. F. V. JACKSON.

Open Cut, Guest's G.M. Co., showing Porphyry Dyke dividing Lodes.

spitzkasten pass to slimes-settling tanks, thence by means of an air lift to agitating tanks of 100* tons capacity, thence through a monte to the presses. The cost to the Company of the above treatment, which is said to result in an average total extraction of about 89* per cent., is £1 0s. 6d.* per ton.

* The Guests Mine.

Year.	Ore treated.	Gold therefrom.	Rate per ton.
	tons.	ozs.	ozs.
1898	60·00	127·60	2·12
1900	7,374·00	5,184·69	·70
1901	10,827 00	3,915·36	·36
Total	**18,261·00**	**9,227·65**	**·50**

The lease is situated immediately to the south of the Westralia Mount Morgans adjoining it, and, since its purchase by the owners of the latter, practically forms part of the same property. The relation of the deposits at the 100-feet level is shown on Plate 7, Fig. 3, and little further description is necessary.

The deposit was worked to the 184-feet level by the Guests Company, and the shaft is sunk on the main ore body, which is adjacent to the intrusive porphyry, the main lode being formed on both sides of a narrow intrusive tongue or dyke of this rock. The ore bodies are now worked at a lower level by the continuation south of the workings of the Westralia Mount Morgans.

The Lily.

This is the next lease south on the line of outcrop.

There are a great number of lodes which have been explored at the 50 feet and 100 feet levels, and except for the occurrence of a number of them in the porphyry, the workings present no special features other than those already mentioned. The position of the lodes is shown (Plate 7, Fig. 3.)

The Millionaire.

Year.	Ore treated.	Gold therefrom.	Rate per ton.
	tons.	ozs.	ozs.
1901	229·00	183·75	·80
1903	5,516·00	2,024·32	·36
Total	**5,745·00**	**2,208·07**	**·38**

* Figures supplied by Metallurgist, April, 1904.

This lease adjoins the Lily on the south, and is the farthest south on the line of outcrops of any of the leases which have been worked to any extent.

The property has been rather more extensively worked than the Lily, but beyond this the mine is in nearly all respects similar, as also the ore deposits, the essential characteristics of which are much the same as those of the Westralia Mt. Morgans.

The three mines have practically the same ownership, and the latter, the Millionaire, is provided with a small treatment plant (Plate 6).

The Fire King.

This lease is situated some 35 chains to the south of the Millionaire.

The lodes may be described as a continuation of the same series of ore bodies and what appears to be their limit in a south-easterly direction, but a break of about 30 chains occurs in the line of outcrops.

The lease was first taken up by Messrs. Clarke Bros., and has since been prospected by a number of different holders, but the work has never advanced past the prospecting stage. The main line of lode has an easterly dip, and several shafts have been sunk along it.

Sundry Leases.

(*North of the Westralia Mount Morgans.*)

A line of leases, now more or less abandoned, extends northwards along the line of outcrops beyond Mount McKenzie, and it is a somewhat remarkable fact that no really payable ore has been found on this side of the big mine. It may be noted, however, that, though a certain amount of prospecting has been carried on, it has been rather inadequate to test the question.

On lease 4327, immediately to the north of the Westralia Mount Morgans, several shallow shafts were put down by the company, and the ore bodies met with are indicated on the horizontal section, Plate 7, Fig. 3. The same remarks apply to lease 4328, where, generally, similar conditions were met with.

The next lease to the north, known as Trig. Hill, has been rather more extensively prospected by several holders, and one of the lodes has been explored by a short tunnel, but results, I believe, have not been very encouraging.

Northwards from this along the old leases only shallow prospecting holes are met with as far as Mount McKenzie, where some prospecting work is in progress at lease 70F and old lease 1106T. The latter, however, is of a rather initiatory character.

Photo. : C. F V. JACKSON.

The Millionaire Mine and Plant.

Lease 70F, Mt. McKenzie North.

Year.	Ore treated.	Gold therefrom.	Rate per ton.
	tons.	ozs.	ozs.
1903	**13·00**	**4·00**	**·30**

This lease is situated on the summit of Mt. McKenzie, which is in a great measure composed of an irregular mass of banded quartz. The lease has been worked for rather more than two years by a prospector named David Bynon, who has driven a tunnel some 160 feet single-handed. Several small trial crushings have yielded from 3 to 6 dwts., and altogether results have not been highly encouraging.

Lease No. 1106F.

This lease is situated about half-a-mile north of Mt. McKenzie, and the workings are at the north end of the line of outcrops, a considerable break in the continuity occurring at Mt. McKenzie. Two prospectors are working here on behalf of a small syndicate, and several shafts have been sunk at different times; but so far no ore in payable quantities has been found.

Gold-bearing Veins of Quartz in Greenstone.

The deposits of this type are situated for the most part to the east of Mount Morgans, and those of importance are three in number, viz., the Transvaal, Sons of Gowrie, and Turn of the Tide.

There are a number of other miscellaneous workings, both on old leases and elsewhere, but they are in a great number of cases abandoned.

The Transvaal.

Year.	Ore treated.	Gold therefrom.	Rate per ton.
	tons.	ozs.	ozs.
1900	266·00	641·37	2·83
1901	393·00	627·20	1·59
1902	72·00	170·00	2·36
1903	680·00	1,494·40	2·19
Total	**1,411·00**	**2,932·97**	**2·07**

The leases are situated about a mile and a-half to the north-east of the township of Morgans. The two principal leases are Nos. 980T and 979T. The prospector of the Transvaal leases, in 1898, was W. J. Hamlin who has owned and worked the property since that date.

There are two main deposits, and these are situated near the northern boundary and near the centre of lease 980. Both are in an area of greenstone which is surrounded by the porphyry on all sides, and comprise several different quartz reefs.

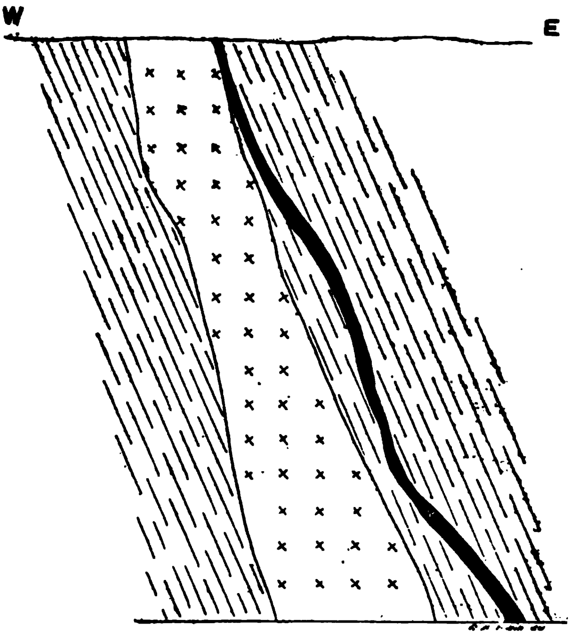
The greenstone is intersected by dykes or bars of porphyry, which, owing to the cover of superficial deposits, can only definitely be traced where exposed in the workings.

The reefs near the northern boundary of the lease are on the eastern edge of the area of greenstone, the strike being almost north and south, the average dip is about 65 degrees to the east.

The principal shaft is that shown just to the north of the boundary on lease No. 927, and in the workings, which are not very extensive, there appear to be several reefs lying approximately parallel to each other, but inclined at a slight angle to one of abovementioned porphyry bars.

The reefs vary from about eight inches to two feet in thickness. The sketch (fig. 2) is a section of the reef as seen at the shaft.

FIG. 2.



VERTICAL SECTION AT MAIN SHAFT. TRANSVAAL. North Workings
MT MORGANS.

The main workings are situated near the centre of the lease, and there are there two reefs, the strike of which is 350 degrees. Operations have been chiefly confined to the more easterly of the two. The dip of this reef, which is 2ft. 6in. in thickness, is about 50 degrees to the east, and the deposit was worked by an inclined shaft. As seen in the workings it is stoped about 4ft. in width for a depth of 30 feet and for a distance of about 50 yards to the north. The inclined shaft was continued, and a vertical shaft also sunk on the back of the reef, intercepting the former at 85 feet, which is rather below water level and at which point it became necessary to cease operations owing to lack of suitable pumps. Serious mining was in abeyance at the time of my visit, pending the arrival of pumps and machinery from England, it being the intention of the owners after the arrival of the plant to continue the vertical shaft to 200 feet.

The Sons of Gowrie.

Year.	Ore treated.	Gold therefrom.	Rate per ton.
	tons.	ozs.	ozs.
1900	80·00	350·00	4·37
1901	159·00	360·00	2·26
1902	203·00	228·80	1·12
1903	134·00	361·75	2·69
Total	**576·00**	**1,300·55**	**2·25**

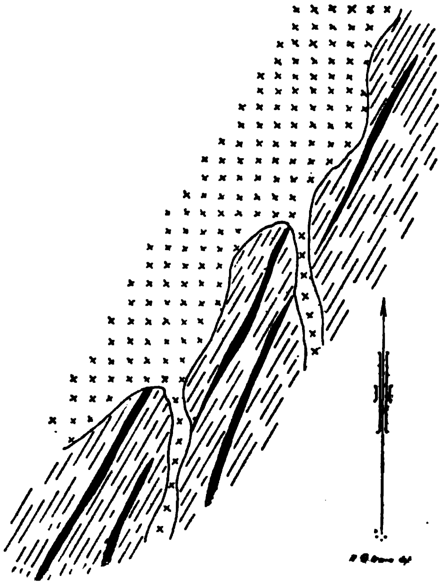
This lease is situated half-a-mile south-east of the Transvaal and about one and a-half miles north-east of the township. The lease was pegged about the same time as the Transvaal by W. Harrison, and at some time during its history was under an option to Mr. G. W. Hall. The property is now being worked by Messrs. McKinna, Vincent, and Smith.

There is a system of parallel reefs, and the deposit, which is in many respects similar to the Transvaal, is on the western edge of an isolated area of greenstone, narrow porphyry bars being of frequent occurrence in the workings. The reefs, however, would seem to be of later date than the intrusive rock, since they appear to taper out on nearing the bars rather than be intercepted by them.

No crosscuts are available for examination, so that a good section is not immediately available, but the following sketch plan (Fig. 3) shows the relation of the reefs and the rocks continuing them. The strike of the reefs is about 208 degrees and the dip 60 degrees to the east. There are a number of shafts on the lease shown on the Geological Map, one of which was carried about 30 feet below water level. There are about 200 feet of drives in the

main workings and a good deal of stoping has been done from the surface to about the 75 feet level.

Fig. 3.



HORIZONTAL SECTION AT 75' LEVEL SONS O'GOWRIE G.M.
MT MORGANS

Turn of the Tide.

Year.	Ore treated.	Gold therefrom.	per ton. Rate
	tons.	ozs.	ozs.
1903	30·00	15·00	·50

The lease No. 100F is situated about three and a-half miles north-east of the township on the boundary of the map.

The property is owned by a syndicate consisting of Messrs. Marmion and others, and is at present under an option to the owners of the Millionaire Mine.

The reef, which is of white quartz, is in greenstone of more or less schistose character, the strike is 285 degrees, and the average dip to the north 65 degrees. It is said to be about eight feet thick in places and to assay well. There are about 80 feet of drives at the 38 foot level, and the shaft has been continued on the foot wall to a depth of 75 feet, at which depth a good deal of water is * being met with.

* April, 1904.

Miscellaneous Leases and Holdings.

A number of prospecting shafts and workings are shown on the map, for the most part on small quartz reefs, and for the development of such holdings the old treatment plant of the Guests G.M. Co. is kept running as a public crushing battery (Plate 8).

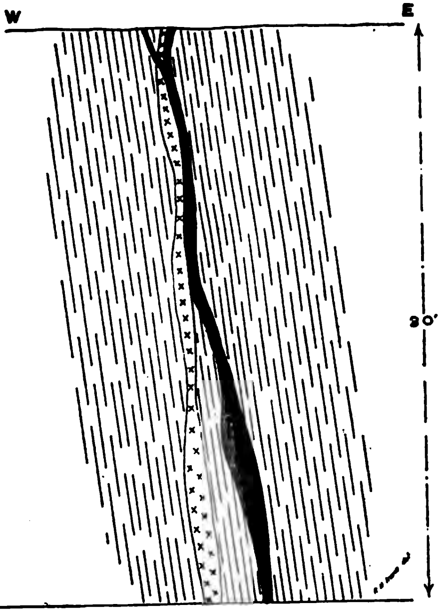
The Ramornie, lease 97F, is situated about three-quarters of a mile east of the township, and is being prospected by Messrs. Archibald and others, with encouraging results. The deposit is in a highly crushed and foliated zone of greenstone, the strike being about 10 degrees east of north; the dip is 80 degrees to the east. The chief characteristic is in the nature of the lode stuff, which is very little different from the surrounding country. The processes bringing about the deposition of the gold in the rock appear to have but very slightly altered the rock itself.

A similar deposit to the Ramornie is being prospected by Messrs. Birrell and Bridges, on the western side of the main ridge, about 30 chains north of the railway station. The dip is here to the west, and developments have been very satisfactory.

There is a group of shafts to the south of the Sons of Gowrie, on the eastern side of lease 1017. These are on some small and very irregular veins in the greenstone schists.

An irregular deposit of a similar character was also worked on old lease 1170T, two and a-half miles north of the township.

FIG. 4.



VERTICAL SECTION SHEWING QUARTZ VEIN. WEBB & PARTY CLAIM.
MT MORGANS.

About a quarter-mile to the east of this, and just to the south of old lease 1123, a vein is being prospected by Messrs. Webb and party, a section of which (Fig. 4) will illustrate the character of most of those on which potholes and shallow shafts have been sunk, between this point and the Turn of the Tide lease 100F, on the eastern boundary of the map.

The strike of the reef is 210 degrees, and the average dip about 80 degrees to the east. The vein is on hard greenstone in juxtaposition to a narrow porphyritic dyke. The quartz is of a bluish colour, and shows pyrites in places.

II.

Notes on the Geology and Ore Deposits

OF

MULGABBIE

(NORTH COOLGARDIE GOLDFIELD).

The Mulgabbie District, with special reference to the occurrence of Telluride Ores.

The output of gold from Mulgabbie has been derived from two sources—

(*a.*) Alluvial flats.

(*b.*) Small rich veins or "leaders."

From the latter the total production to the end of 1902, as defined by the authorities, is made up as follows:—

Year.	From Specimens.	From Ore.	Total.
	ozs.	ozs.	ozs.
1898	44·60	...	44·60
1899	...	...	...
1900	897·42	147·80	1,045·22
1901	620·65	123·76	744·41
1902	6·60	190·04	196·64
Total	1,569·27	461·60	2,030·87

From 7 tons ore. From 8 tons ore. From 53·25 tons ore.

With regard to the quantity of alluvial gold obtained, there is no information which will enable the amount to be stated, since the production from this source is included in the official statistics with that of the Kurnalpi district generally.

Mulgabbie is situated in the North Coolgardie Goldfield, 40 miles north and 58 miles east of Kalgoorlie. It is most easily accessible from Kanowna, the distance by a somewhat circuitous road, which passes through the old Kurnalpi field, being some 78 miles.

The discovery of payable gold was made in 1897 by three prospectors—Messrs. Reid, Mackay, and Johnson—though previous rumours of gold in the locality had originated from some men who were cutting timber for the Edjudina mines.

In the report of the Under Secretary for Mines for 1897, the warden of the North-East Coolgardie Goldfield mentioned Mulgabbie, and stated that 150 men had been engaged prospecting there during that year; but though a few hundred ounces of gold had been obtained, the true value of the discovery was not then known. During the next two years it appears, from the warden's reports, that alluvial gold continued to be obtained, the field supporting a population varying from 60 to 100; but at the end of the following year (1900) that gentleman reported that the known alluvial workings, both at Mulgabbie and Kurnalpi, appeared to be worked out. A fact indicated by the tabulated statistics above, which further shows a rapid decrease in the amount of gold obtained from rich surface specimens. A gradual increase, however, is shown in the amount of gold obtained by more regular mining work.

Most of the prospecting in the locality has been confined to a small area about 30 chains to the north-east of the Mulgabbie trigonometrical station, where a number of shallow shafts have been sunk; and on the recent discovery of telluride ores in one of these shafts, some 30 or more 24-acre leases, extending on either side in a north-westerly and south-easterly direction, were quickly pegged out and surveyed. The accompanying Geological Sketch Map of Mulgabbie, based on this new lease plan, comprises a rectangle of five square miles, of which the Mulgabbie Hill approximately forms the centre.

This hill, of somewhat conical form, which rises to a height of 150ft. above the alluvial flat below, and rather more than 200ft. above the general level of the surrounding country, forms a prominent landmark from the south and west. The alluvial flats, which form a central feature of the map, are flanked on either side by prominent ridges with an approximately north-west axis, and thus form a small catchment which drains more or less directly to the salt pans or lake to the south and east.

The rainfall, however, is not very large, and may be approximately known from the records kept at Kurnalpi, which show for the last five years a mean of 7·5 inches.

A geological examination of the district has shown that the formation of chief importance consists of a system of basic rocks, appearing in the form of schists and weathered greenstone outcrops; and there are also several areas occupied by an intrusive porphyry. The latter are of small extent, but the former rocks cover a very large area, which, however, is concealed in many places by a considerable development of laterite.

Approaching from the south, large outcrops of granite are to be seen 16 miles distant, and about three quarters of a mile east of

the road, and thence for eight miles the rocks are obscured either by a recent superficial deposit of sands or by the above-mentioned laterite; for the next five miles the road passes chiefly over the salt marsh or lake country, in the bed of which the decomposed and weathered basic rocks are sometimes visible; but it is not until a point is reached some three miles south of Mulgabbie that these rocks begin to outcrop in their characteristic form.

North of Mulgabbie, a second larger outcrop of granite makes its appearance at Calvali, four miles distant, the chief characteristic of the rock being the frequent occurrence of large crystals of a twinned felspar.

The greenstones, or diabasic rocks, occur in more or less crushed and highly-altered forms, but within the scope of a field examination present no important features other than those observed elsewhere. It is possible, however, that a more extended investigation might lead to a separate mapping of the schists. The direction of foliation varies from about 120 to 160 degrees, and, with few exceptions, there is a tendency to a westerly dip throughout the district.

The most important exception is that of the porphyritic rock forming the Mulgabbie Hill, which shows considerable crushing, and the joints developed, though very nearly vertical, have, if anything, a tendency to an easterly dip. The outcrops of this rock appear to be somewhat isolated, and those showing on the map, as far as can be judged, wholly detached; but on this point it is somewhat difficult to be certain where the surface is largely covered with more recent superficial deposits, and the rocks considerably decomposed. The intrusion seems to have taken a north-westerly course, and I was informed by prospectors that further similar outcrops appear some eight or nine miles to the south, on the southern side of the lake. The porphyritic mineral, ordinary felspar, appears in a fine-grained matrix in the form of numerous small crystals of the characteristic shape.

Mining.

The chief development of rich highly-inclined veins or leaders, to which mining operations are confined at present, has been on the western side of the alluvial flats, in a small area included within the boundaries of leases 261k, 34k, 263k, 39k, and 260k (*see* Sketch Plan, Plate 9), and from these, by the degradation of the rock containing them, the gold obtained from the adjoining flats has been derived. Most of this gold was found at a depth of from 10ft. to 14ft., on the surface of the decomposed basic rock beneath; and as will be seen on reference to the plan, the workings cover in all an area of about 25 acres.

Of the veins or "leaders," those on which attention has been chiefly centered are distinguished on the plan as No. 1 and No. 2, and a considerable amount of gold was obtained by dollying rich specimens taken from the outcrop of each. Deeper exploration,

however, has been principally confined to the No. 1 or Eastern vein, and on this a number of shafts have been sunk at different points; but most interest at present attaches to that marked No. 5 originally on Q.C. 6k, now on lease 260k.

Lease No. 260k.—There are in all some eight or nine shafts on this lease, and the working shaft No. 5 is now (since the recent survey) known as the prospector's shaft. This shaft was originally sunk in the year 1900 to a depth of 69ft., and Messrs. Robb and party, who obtained possession in 1902, have since connected the workings with the No. 4 shaft and operated to a depth of 100ft.

The shaft follows the main "leader," the average dip of which has been about 75 degrees to the west and south; the mean strike about north 56 degrees west. The thickness has varied from two inches, or two and a-half inches, to a mere joint in the massive rock (greenstone) containing it; and the latter is traversed by a number of similar parallel leaders, all more or less auriferous.

In addition to quartz, the "vein filling" consists of crushed rock material with a little pyrites appearing in the lower levels; and the leaders appear to have been formed in a system of joints along which the main mass of the rock has "yielded" to forces which have produced the schistose form occurring in larger areas in the immediate vicinity.

The rock has also "yielded" to a somewhat greater extent and become highly foliated, along several zones of weakness extending in the same direction; one of which passing through the main workings is there called "the indicator," elsewhere they are known as "slate bars" from the appearance of the decomposed outcrops, in places, being somewhat similar to that of a slate. The information, however, with regard to the genesis of lodes in the greenstones elsewhere, and the complete alteration from a basic rock to a siliceous lode formation, leads to the conclusion that the slate-like appearance here and there noticeable is due to a transition stage in that process.

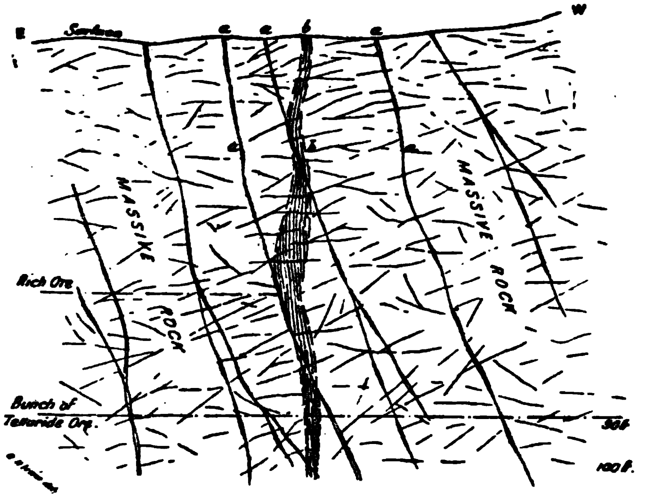
The "indicator," composed of a hard compact chlorite schist showing a little sulphide in places, has varied in thickness from two or three inches, to two or three feet, and appears to have had some influence on the distribution of gold in the auriferous veins.

In the No. 5 shaft, which followed the main leader, the "indicator" was met with at 40 feet, and from this point, the leader remained on the footwall side of the formation for some distance. It was observed that most of the good ore occurred in small rich patches along the junction plane.

At a greater depth the leader crossed the zone of foliated rock passing to the west, and in the acute angle thus formed a small

"bunch" of telluride ore was met with on the western side at a mean depth of about 90 feet. (Fig. 5.)

Fig. 5.



a ...... Auriferous Veins or "leaders". b.... Zone of Foliated Rock "Indicator"

MULGABBIE

This find was made in October of 1903, and some specimen pieces have been left on the wall, showing a good deal of free gold in association with the telluride "Petzite"; but very little work has since been done, and the prospectors appear to have removed the greater portion of the telluride ore, actually in sight, in a parcel of one and a-half tons from which they obtained 60 ounces of gold locally as well as a further quantity by treatment of tailings and slimes sent to Kalgoorlie.

Some samples collected by the Inspector of Mines in November of 1903 were examined in the Geological Survey Laboratory, and the following is an extract from a report thereon by the Mineralogist and Assayer :—

Sample No. 1 contained a considerable amount of pyrites in bands and lenses, mostly along the planes of foliation of the rock. A narrow irregular vein of carbonates of lime and iron, with some quartz, cut across the foliation planes.

Free gold was visible in most cases throughout this vein, associated with a black metallic mineral and a light coloured mineral. The former was present in sufficient quantity to enable its identity to be established as Petzite, a telluride of gold containing about 24 per cent. of gold and 41 per cent. of silver. The light coloured mineral was present in such small scattered fragments that it was impossible to definitely ascertain its species, though it is probable that it is calaverite, a telluride containing 40 per cent. of gold. After removing pieces showing gold freely the general sample assayed gold 18ozs. 12dwts. per ton, silver 7ozs. 17dwts. per ton.

A portion of the vein, which showed no free gold to the eye, assayed gold 6dwts. 13grs. per ton, silver 7½dwts. per ton.

Sample No. 2 assayed, gold 18dwts. per ton; silver trace.

Sample No. 3, strongly impregnated with pyrites, assayed as follows:—

(*a*.) Pyritous portion, gold trace, silver 6½dwts. per ton.

(*b*.) Non-pyritous portion, gold trace, silver 6½dwts. per ton.

A number of rich specimens have been preserved at the mine, but beyond that, in most cases the mineral "Petzite" was present in considerably greater proportion than would appear to have been the case in the samples taken by the inspector. I am unable, after an examination of all available examples, to add to the information quoted above.

At the present depth of 100 feet and in "hard country," it is difficult for the unaided prospector to make much progress; and where the only means of treatment is a small three-stamp prospecting battery, at which the charge for crushing is £2 per ton, it is only by the acquisition of an occasionally rich parcel that his enterprise is assisted. It is to be regretted, however, that more work has not been done, for beyond a somewhat visionary improvement, the conditions of mining in the district have been very little altered by a discovery, the importance of which certainly warrants more thorough investigation being made.

Quartz Claim, No. 39k.—This claim adjoins lease No. 260k, on the south, and the working shaft thereon is that marked No. 6. The shaft was originally sunk by a prospector named Johnson to a depth of 20 feet, and in 1901 passed into the possession of the present owners, Messrs. Thompson and party, who have continued sinking to 90 feet. The workings are a continuation of the deposit already described, the intercept of leader and "indicator" being met at a depth of 70 feet. The former presents the same features, but the latter is somewhat larger, and at the bottom of the workings, mineralised to a considerable extent with ordinary sulphides for a width of about 12 inches on one side, and to a lesser extent over a somewhat greater width. The "leader," which follows the hanging wall for some distance, carries gold, as also the mineralised portion of the rock, but so far only in association with pyrites. There is in all a formation exposed about 2 feet 6 inches in thickness.

Lease No. 263.—The next in order southwards is held by Messrs. Cable and party, but it was not (in February, 1904) being worked. Included within its boundaries is a considerable amount of surface working, and a number of old shafts, from one of which No. 7, sunk on the main leader by Messrs. Audrey and Johnson, some 500 ounces of gold are said to have been obtained at a depth of 28 feet, also a further larger quantity at 45 feet.

Quartz Claim, No. 34k is held by Messrs. Clancy and Anderson, and the deposit is here being worked from shaft No. 9 on the south boundary, at a point 10 chains south of the prospectors. This shaft is 76 feet deep, and not yet below the decomposed

rock. The same "leaders" and zone of schistose rock are recognisable, the junction being met with at about 40 feet, but below this there is no very strong line of demarkation, the "leader" or "leaders" having entered the crushed zone. The whole thus forming a body which may be described as of mullocky formation, showing in places a considerable amount of undecomposed sulphides, and varying in thickness from two to five feet. This formation, independent of the leaders contained therein, carries in places a payable quantity of gold.

South of this claim, goid has been obtained from surface workings, and a number of shallow shafts extend along the outcrop of the leader for a distance of 10 chains; which appears to be the limit of its proved extension in that direction.

Quartz Claim, No. 40k.—The workings on this claim, which occupies a small area almost in the centre of the prospector's lease, No. 260k, are at a point of the deposit beyond which it has not yet been traced in a northerly direction. The claim is being worked by Messrs. Glover and Johnson, and the working shaft, No. 2, is 75 feet deep; there are in all three shafts, connected by a drive at 38 feet. The vein here appears to have been faulted, or otherwise slightly displaced, and the total amount of gold obtained from the workings is said to have been about 200ozs.

Lease No. 266k—situated 30 chains to the north-west, is, in conjunction with that adjoining (No. 265k), being worked by Messrs. Simmons and party. On the latter, shaft sinking has only just been commenced but, on the former, there are a number of abandoned shafts.

Those marked on the map in the north-east corner of the lease, were sunk on a small leader dipping at a high angle to the west, the strike being 140 degrees; and a good deal of material was removed from the outcrop by means of a deep trench.

Near the south-east boundary is another group of shafts, the deposit worked being a similar small vein or veins which were explored to a depth of 90 feet. From one of these veins some 500ozs. of gold is said to have been obtained.

The prospecting work on this lease at present is being directed towards exploring a formation, which appears on the surface as a large ferruginous outcrop of schists, crossing the lease in the form of a low ridge, and has yielded a little gold to the dryblower on either side.

Lease No. 272k is situated 35 chains south of the prospectors' lease and is held by Messrs. Welsh and party. There are a number of shallow shafts in proximity to one of the "slate-bars" previously mentioned, and gold was found similarly disposed in "leaders" from which a number of small parcels were obtained by different prospectors.

Lease No. 262k is the next lease adjoining southward, and from three shallow shafts situated thereon several small lots of rich

ore were obtained. The deposit worked, of small dimensions, was similar to the other veins in the locality.

Lease No. 271k.—Of the shafts and workings shown on this lease, those with the more northerly situation are practically only trenches, while those in the more southerly portion are sunk to a depth of 50 feet on two small veins. These veins have a strike of 165 degrees, and are almost vertical.

Lease No. 275k.—The shaft shown on this lease is an old water shaft, which is 60 feet deep, but was unsuccessful in its object.

Lease No. 270k is not being worked at present, but there is an old shaft thereon which was sunk by Messrs. Cole and Bartley to a depth of 40 feet on a small vein dipping at a high angle to the west.

Lease No. 290k includes a portion of an old abandoned lease known as Heydon's Hope (No. 230k), from which, as shown by the official statistics, 44ozs. of gold were obtained by dollying rich specimens in 1898.

Lease No. 247 (voided).—This lease was originally known as the Dolly Vane, and a new 24-acre lease has recently been taken up surrounding it. There are three old shafts sunk in the schists, to a depth of from 50 to 70 feet, and the auriferous deposit consisted of a quartz reef with a strike of 72 degrees east of north. The dip is towards the south. I was informed by the prospectors that the quartz had an average width of three feet, and further that a crushing of five tons yielded 30dwts. per ton.

Lease No. 286k, a new lease adjoining, has been taken up by Messrs. Bayley and party, and there are some surface workings and a shaft in course of sinking about 15 chains to the north-west.

In conclusion, it may be said with regard to the area examined, that its resources, so far as alluvial gold is concerned, appear to have been exhausted; and that mining operations, limited at present to a depth of 100 feet, have been entirely confined to veins, very rich in places, but too small for profitable mining enterprise. The workings, however, have exposed a formation, portions of which have yielded an assay value ranging from 10 grains per ton to 1oz. 15dwts. per ton, and to the speculative value of which a great deal has been recently added by the appearance in the deepest workings of the mineral "Petzite."

C. F. V. JACKSON,
Assistant Government Geologist.

APPENDIX.

Descriptive Register of Specimens from Mount Morgans and Mulgabbie.

MOUNT MORGANS.

Register No.	Rock. Field Class.	Rock. Variety.	Obtained from.	Locality.
5668	Greenstone	Massive ...	Shaft...	Just to south of Lease 1123
5674	Do. ...	do. (coarse-grained)	Surface	Near Lease 110F
5676	Do. ...	Massive (fine-grained)	do. ...	East of Lease 1229T
5672	Do. ...	Schistose ...	Shaft...	Lease 100F
5683	Do. ...	do. ...	do. ...	Westralia No. 6 level
5670	Do. ...	do. (mineralised)	do. ...	Lease 980
5684	Do. ...	Altered ...	Mine ...	E. crosscut, Westralia
5671	Porphyry	Quartz Felspar	Surface	West side, Lease 1102
5666	Do. (dyke)	do. ...	Shaft...	South of Lease 1123
5669	Do. ...	do. ...	do. ...	N.E. corner of Lease 980
5673	Do. ...	Felspar ...	Surface	Near Lease 1121T
5679	Do. ...	Quartz Felspar	Shaft...	Lease 1081T
5685	Do. (crushed)	do. ...	Mine ...	400-ft. level, Westralia
5686	Do. (crushed)	do. ...	do. ...	do. ... do.
5676	Quartz ...	Banded ...	Surface	Mt. McKenzie
5667	Do. ...	Vein	Shaft...	South of Lease 1123
5680	Ore ...	Typical variety	Mine ...	Westralia
5681	Do. ...	do. ...	do. ...	do. 300 level
5682	Do. ...	do. ...	do. ...	do. 500 „

MULGABBIE.

Register No.	Rock. Field Class.	Rock. Variety.	Obtained from.	Locality.
5691	Greenstone	Massive ...	Shaft...	Shaft No. 5
5692	Do. (indicator)	Foliated ...	do. ...	do.
5694	Greenstone	Altered ...	Surface	Mulgabbie
5693	Porphyry	Felspar ...	do. ...	Mulgabbie Trig.
5695	Granite ...	Coarse ...	do. ...	4 miles north of Mulgabbie (Calvalli)
5696	Do. ...	do. ...	do. ...	16 miles south of Mulgabbie
5690	Ore ...	Telluride ...	Shaft...	Shaft No. 5

INDEX.

The Figures in Italics refer to Plates and Diagrams.

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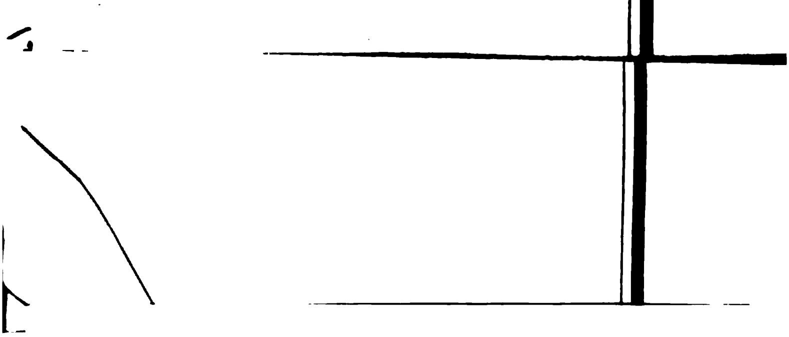
BULLETIN Nº 18 PLATE VII.



1905.

WESTERN AUSTRALIA.

With the Government Geologist's Compliments.

GEOLOGICAL SURVEY.

BULLETIN No. 19.

MINERALS OF ECONOMIC VALUE,

BY

EDWARD S. SIMPSON, B.E., F.C.S.,

Mineralogist and Assayer.

Issued under the authority of the Hon. R. Hastie, M.L.A., Minister for Mines.

PERTH:

BY AUTHORITY: WM. ALFRED WATSON, GOVERNMENT PRINTER.

1905.

TABLE OF CONTENTS.

PREFATORY NOTE.

THE notes which form the subject matter of this *Bulletin* were compiled by Mr. E. S. Simpson, primarily for the purpose of meeting a much needed want on the part of the different members of the staff in dealing with the numerous inquiries on the part of the general public, in connection with what may be called Commercial Mineralogy.

A good deal of the information is scattered through various scientific and other serial publications, which are not readily accessible, and it has been felt that the publication of the data would possibly serve a much felt want in the State.

Especial reference has been made in the report to those minerals which have so far been found to occur in Western Australia, and the figures in heavy type refer to the registration number of the specimens in the collection of the Geological Survey, thus facilitating reference at any time.

The manuscript, on being submitted to the Hon. the Minister for Mines, was ordered to be printed for public information.

The index has been prepared by myself.

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MINERALS OF ECONOMIC VALUE.

INTRODUCTION.

The notes upon which this *Bulletin* has been based were first prepared at odd intervals during the last five years in order that information might be given to officers of the Geological Staff and unofficial inquirers in regard to the less well-known minerals which have a market value either locally or in the great centres of the world's manufacturing industries.

For many years gold was almost the only mineral which attracted the attention of the lay and expert public in Western Australia, but recently more frequent inquiries have been made with regard to other sources of mineral wealth. In order to meet these, and if possible interest a larger number of prospectors and others in our latent possibilities in other directions, the original notes have been considerably enlarged and cast into a suitable form for publication.

A review of mineral statistics for the past few years shows that the five most valuable mineral products of the world are coal, clay, gold, iron ore, and petroleum. The total production of these in the whole world during 1903 may be roughly estimated by the following figures :—

Coal	£250,000,000
Clay	80,000,000
Gold	60,000,000
Iron ore	40,000,000
Petroleum	30,000,000

If the space devoted to each mineral in the following pages had been therefore dependent upon its value to mankind, an overwhelming proportion of the *Bulletin* would have been devoted to these five mineral groups. All of them are, however, of wide distribution and readily recognised, so that they have not been dealt with at any great length. Rather has it been deemed advisable to describe more fully the lesser known species, which from their rarity often command exceptional prices.

This *Bulletin* does not pretend to be a text-book of Mineralogy; it has, however, been found necessary, in order to facilitate the recognition of the various minerals, to give a short description of the appearance and character of each. In the case of precious stones this description has necessarily been in somewhat more detail than in the case of other minerals. In these descriptions the symbol "G" has been used instead of the words "Specific Gravity,"

and the symbol "H" for "Hardness" according to Mohr's scale. The following approximate terms have been used in connection with the hardness:—

Hardness	1.	Talc	Very soft
"	2.	Gypsum	" "
"	3.	Calcite	Soft
"	4.	Fluorite	"
"	5.	Apatite	Hard
"	6.	Feldspar	"
"	7.	Quartz	"
"	8.	Topaz	Very hard
"	9.	Sapphire	" "
"	10.	Diamond	" "

Wherever possible reference has been made to specimens in the Museum of the Geological Survey.

The commercial value of most minerals depends upon their freedom from mechanically admixed impurities and upon their chemical composition, which even in absolutely clean, pure specimens is liable to some slight variation due to isomorphous replacement. Even traces of certain substances present from either of these causes at times have a marked effect upon the value of the bulk sample. For this reason, as far as possible, these objectionable constituents have been pointed out in the following pages. The percentages of the various constituents given are those found in the clean mineral freed from all mechanical impurity.

The many works referred to in preparing these notes cannot all be indicated, but I am especially indebted to the various volumes of the "Mineral Industry," to Dana's "System of Mineralogy," Browning's "Introduction to the Rarer Elements," Wagner and Crooke's "Manual of Chemical Technology," and Streeter's "Precious Stones and Gems."

ALUMINIUM.

Aluminium compounds are amongst the commonest constituents of the earth's crust, but it was not till 1827 that the pure metal was first prepared, whilst it is only within the last fifteen years that the cost of its production has been so cheapened as to bring it into rivalry with other more familiar metals.

The chief properties of aluminium which give it its present high importance in the arts are its lightness (its specific gravity is only 2·7 or about one-third that of iron), strength, high electric conductivity, non-poisonous character of its compounds, pleasing silver-white colour not readily tarnished or corroded, sonorousness, great affinity for oxygen, and finally the great modifications it produces in the properties of other metals when alloyed with them. It is also very malleable and ductile and a good conductor of heat.

Though compounds of aluminium are very abundant in nature, but few of them can be utilised as a source of the metal or its compounds. The most important of these are the hydrates, bauxite, gibbsite, and diaspore, and the double fluoride of sodium and

aluminium known as cryolite. Clay, felspar, and other silicates of aluminium with other metals, are seldom if ever used as a source of the metal or its definite compounds, and with the exception of clay will be dealt with under another heading (*see* page 11).

The best commercial aluminium contains 99 to 99½ per cent. of the pure metal, the balance being mainly silicon and iron. Inferior grades of metal contain 92 to 99 per cent. of the pure metal. Aluminium is largely used for cooking and other domestic utensils, for army equipments, field glasses, and other uses where lightness and durability are essentials. Its sonorousness and lightness have led to its use in sounding boards for musical instruments and large public halls. Weight for weight, aluminium is about as strong as the best steel and is much more durable, so that it is capable of replacing that metal to a large extent where expense is a secondary consideration. It has largely replaced silver for toilet, ornamental, and surgical articles, and as foil. Lithographic plates have been made of aluminium, as well as horseshoes, parts of vehicles, scientific instruments, etc. Powdered aluminium has a strong affinity for oxygen, and is therefore used for the production of flash-lights, the reduction of many metals from their ores, and the prevention of flaws in steel and iron castings.

The most important alloys of aluminium are those with copper known as aluminium-bronzes. These alloys are light and very strong and resist corrosion, with the result that they have been largely used for racing yachts, flying-machines, propellers, etc. Ferro-aluminium, an alloy of iron and aluminium, is prepared to add to steel to produce sound castings or render it more easily welded. Various alloys of aluminium with nickel, copper, zinc, etc., are used for ornamental and other purposes.

Many artificial compounds of aluminium are used in the arts, chief among them being alum, sulphate of aluminium and potassium. This is largely used in sizing paper, dyeing, manufacture of the pigments known as "lakes," hardening plaster of Paris, tanning and curing, clarifying water and other liquids, purifying sewage, etc. Aluminium sulphate is used for the same purposes as alum. Sodium aluminate is used in dyeing and printing, in hardening natural stone and making artificial stone, and in stearine candle manufacture. Aluminium acetate is used in dyeing. Ultramarine, a brilliant blue compound of aluminium, sodium, sulphur, and silica, is extensively used as a pigment and dye, and for blueing linen, paper, sugar, candles, etc.

Aluminium oxide (alumina), hydrate, chloride, and fluoride are manufactured on a large scale as intermediate products in the conversion of ores into metallic aluminium.

Corundum.—Oxide of aluminium, Al_2O_3. Aluminium, 53 per cent. The impure variety known as emery contains iron oxide, and is therefore poorer in aluminium. Crystallised, massive, or granular. Grey or tinted, translucent. (The rare transparent highly-coloured varieties are valuable gems, *see* Ruby and

Sapphire.) Very hard, brittle. G., 4·0. Found in veins or pockets in crystalline rocks, or in river gravels.

Uses.—Chiefly used as an abrasive, though to a slight extent it has been smelted into metal. For either purpose the purer the mineral the more valuable it is. Mechanically admixed impurities can be removed by mechanical concentration, but not so the iron oxide in the darker varieties known as emery. Exceptionally pure hard crystals fetch a high price for cutting and polishing diamonds and other gems.

Bauxite.—Hydrate of aluminium, with various proportions of hydrate of iron. Aluminium, 18 to 39 per cent.; alumina, 35 to 74 per cent. Massive, earthy, or concretionary. Grey, yellow, brown; opaque. Soft or hard. G., 2·5. Occurs very rarely in veins; commonly in superficial deposits produced by the weathering of crystalline rocks *in situ*, or the collection in lake beds or hollows of the products of denudation.

Uses.—This is the most important source of the metal and its compounds. Its value depends directly upon the percentage of alumina present, and upon the smallness of the iron content. Bauxite with more than 3 per cent. of iron oxide is of little value for the production of alum, etc. Most bauxites contain some silica and alumina in combination as kaolin; an ore containing any given amount of alumina and silica is of less value when these constituents are chemically combined than when they are merely mechanically intermixed. Bauxite is also used in the manufacture of very high grade and refractory crucibles and firebricks.

T. 197.—High grade Bauxite, Georgia, U.S.A.

T. 198.—Clay-like Bauxite, Co. Antrim, Ireland.

3148.—Ferruginous Bauxite, Smith's Mill. Contains alumina, 47 per cent.; iron oxide, 10 per cent.

997.—Ferruginous Bauxite, Wongan Hills. Contains alumina, 45 per cent.; iron oxide, 19 per cent.

Gibbsite.—Hydrate of aluminium, with sometimes oxide of iron. Aluminium, 32 to 34 per cent.; alumina, 60 to 65 per cent. Much so called bauxite is in reality gibbsite, or a mixture of the two. Crystallised, massive, concretionary, or stalactitic. White, grey, yellow, red; translucent or opaque. Soft, tough. G., 2·4.

Uses, etc.—Same as bauxite.

Cryolite.—Fluoride of aluminium and sodium, Na_3AlF_6. Aluminium, 13 per cent. Crystallised or massive, cleavable. Colourless, white or tinted, transparent or translucent, glassy lustre. Soft, brittle. G., 3·0. Occurs chiefly in Greenland in a vein in granite.

Uses.—A valuable ore of aluminium owing to its easy fusibility, and capacity for dissolving alumina. It is also used as a constituent of a variety of glass.

T. 196.—Cryolite, Ivigtut, Greenland.

Kaolin.—Hydrated silicate of aluminium. Aluminium, 20 per cent.; alumina, 39 per cent. Massive, compact, friable, or scaly. White, grey, or tinted. Opaque; scales, translucent. Soft. G., 2·6.

Clay is mainly kaolin admixed with more or less finely divided quartz, felspar, iron oxide, or organic matter, and occurs either in sedimentary beds or *in situ* as the result of weathering of igneous rocks.

Uses.—Clays vary largely in composition, colour, plasticity, and behaviour under heat, and according to the variations in these properties are found suitable for various purposes. An actual manufacturing test is the most satisfactory, and in some cases the only way of determining their utility. According to their purity, clays may be divided for commercial purposes into three classes, as follow:—

China Clay.—This is the purest form of kaolin used in the manufacture of porcelain and china, and to a less extent as a "filling" for paper. Finely divided quartz up to 25 per cent. does not decrease its value, but it must be sufficiently free from oxide of iron to remain white after baking, and also be sufficiently infusible to resist melting during that process. For the latter reason it must be free from any notable amount of lime or alkalies. The more plastic the clay, and the less shrinkage experienced in baking, the more valuable is it. Workable deposits of this variety of the mineral are usually in the form of irregular surface masses, resulting from the decomposition *in situ* of granite, though they are occasionally found in alluvial deposits.

Fire Clay.—The clays used for making refractory bricks, etc., are usually not as pure as china clay, but should not contain more than four per cent. of impurities other than quartz and organic matter. The best clays for this purpose are usually found in the coal measures immediately beneath the seams of coal, though they may also be found in similar situations to china clay. The best fire clays will stand intense heat without fusion or great shrinkage, will resist to a large extent the corroding action of fused mineral substances, and are not affected by sudden and great changes of temperature.

The finest grades of fire clay are employed in the manufacture of pots for melting glass, but by far the largest proportion of the total production is converted into fire brick for fire-places and furnaces, and as mortar to bind fire bricks. Large quantities are used for making crucibles for assaying and other purposes. Poorer qualities are used to make stone-ware, drain pipes, etc. The refractoriness of a fireclay depends almost entirely upon its chemical composition, more than 5 per cent. of fluxes (oxides of lime, iron, alkalies, etc.) reducing its melting point considerably. The more plastic a fire clay, the denser and stronger will be the resultant fire brick, but the greater will be the shrinkage on burning.

Brick Clay is the commonest and least pure of all useful clays. Any ordinary clay can be made into bricks, but the best are made from clays containing not less than 60 per cent. of kaolin, only a very small proportion of coarse sand, and free from pyrites and from concretions of iron oxide or carbonate of lime.

Alum Shale is a clay rock containing a considerable proportion of pyrites or marcasite, which on weathering, or roasting and leaching, yields aluminium sulphate and alum.

2563.—China Clay, North Lead, Kanowna.
2538.—Fire Clay, North Lead, Kanowna.
3152.—Fire Clay, Smith's Mill.
2736.—Brick Clay, North Lead, Kanowna.

Alunite.—Hydrous sulphate of aluminium and potassium. Alumina, 37 per cent.; potash, 11 per cent. Massive or crystallised. Soft, brittle. White, grey, or pink. Transparent to almost opaque. G., 2·6.

Occurs as irregular pipes or veins in trachytic or granitic rocks.

Uses.—A common source of alum and aluminium sulphate.

ANTIMONY.

Antimony has been known from time immemorial, an ancient Chaldean vase having been discovered made of this metal. It is a brilliant silver-white metal, coarsely crystalline in structure when melted and cooled slowly, but granular when quickly cooled. It is hard and very brittle, not affected by the air at ordinary temperatures, but, on heating, burns with the production of the oxide. It is attacked by most mineral acids.

The metal occurs native in several parts of the world, usually in veins in crystalline rocks. It is not, however, an important ore. The most common ore is the sulphide, stibnite, which, at the surface, is found altered to one or other of the oxides, cervantite, etc. An oxysulphide, kermesite, has been mined in Italy. Antimony ores occur in veins of quartz or calcite in slates, granites, and other crystalline rocks.

Though known for so long, the use of antimony in the arts has never been very extended; even now, practically, its only use is in the form of alloys with other metals, which are thereby rendered harder and more lustrous. The most important of all antimony alloys are those with lead. Type metal is an alloy of lead, tin, and antimony. The hard lead used for coffins, and for pumps and pipes, and acid chamber linings in chemical factories, contains several per cent. of antimony. Britannia metal, pewter, and many anti-friction metals contain a considerable percentage of this metal. Much of the antimony used for the preparation of these alloys comes into the market in the form of antimonial or hard lead, a by-product of lead smelters. It contains 18·27 per cent. of antimony.

Of artificial compounds, the most important is the tri-sulphide, which is one of the chief constituents of the heads of safety matches, and is also used in pyrotechny and medicine. The penta-sulphide is used to vulcanise caoutchouc. Potassium antimonate, or tartar emetic, is used in medicine and as a constituent of certain varieties of glass. Neapolitan yellow, lead antimonate, is used as a pigment, and as a constituent of stained glass. Antimony-cinnabar (an oxy-sulphide) is used as a pigment.

Stibnite.—Trisulphide of antimony, Sb_2S_3. Antimony, 71 per cent. Coarsely or finely crystallised, massive or granular. Lead coloured and brilliant or iridescent; opaque. Very soft and easily fusible. G., 4·6.

Uses.—This is the chief ore of antimony and most important source of the metal and its compounds. For export, it should be dressed by hand or otherwise up to at least 50 per cent. By heating it may be melted and run off from the gangue and cast into ingots for export. The value of the concentrates will depend not only on their contents in the metal but also on their freedom from compounds of arsenic and lead, and in many cases upon the proportion of gold and silver present.

> 5028.—Massive Stibnite, Mallina.
> 3706.—Crystallised Stibnite, Mt. Magnet.
> 1374.—Crystallised Stibnite, Metz, N.S.W.

Kermesite.—Oxysulphide of antimony, Sb_2S_2O. Antimony, 75 per cent. Usually crystallised. Red, opaque, brilliant lustre. Very soft, sectile. G., 4·5.

Uses.—Sometimes occurs in sufficient quantity to form a source of the metal.

Valentinite.—Trioxide of antimony, Sb_2O_3. Antimony, 83 per cent. Crystallised or massive, granular. Brilliant lustre; white, pink, or grey; translucent. Soft. G., 5·6.

Uses.—Used as a source of the metal and its compounds.

> 1364.—Crystallised Valentinite, Hillgrove, N.S.W.
> T. 10.—Massive Valentinite, Borneo.

Cervantite.—Tetroxide of antimony, Sb_2O_4. Antimony, 79 per cent. Crystallised or massive. Yellow, opaque. Soft, brittle. G., 4·0.

Uses.—Used as a source of the metal and its compounds.

> 1921.—Massive Cervantite, Wiluna.
> 5195.—Cervantite crust on Stibnite, Mallina.

ARSENIC.

Arsenic in its properties lies on the borderland between the metals and the non-metals. It was known to the Ancient Greeks. It is a steel-grey crystalline solid of metallic appearance, brittle, and a good conductor of electricity. It tarnishes rapidly in moist

air, and when heated volatilises without melting. It is somewhat lighter than antimony.

Arsenic occurs occasionally uncombined in nature, but its commonest ore is mispickel, a sulpharsenide of iron. Sulphides of arsenic occur native, as also arsenides of iron nickel and cobalt. Arsenic and its compounds usually occur in veins in crystalline rocks.

The element has no use in the arts except to add to lead for making shot.

Of its artificial compounds the most important is the trioxide, known as white arsenic. Owing to its extremely poisonous character large quantities of white arsenic are used to destroy vermin and insect pests, and also as a preservative of timber, skins, leather, etc. It is also used to prevent and cure foot-rot in sheep. Large quantities are used to produce several green pigments (notably Paris green), which are compounds of this oxide with oxide of copper, etc. It also enters into the composition of some varieties of glass. Several compounds of arsenic are used in medicine.

Mispickel (Arsenical Pyrites, Arsenopyrite).—Sulpharsenide of iron, FeAsS. Arsenic, 46 per cent. Crystallised or massive. Light grey, metallic, brilliant, opaque. Brittle, hard. G., 6·0.

Uses.—Used as a source of white arsenic, etc. Some samples contain a notable proportion of gold or cobalt, which will pay for extraction, when white arsenic may be collected as a by-product during the necessary roasting.

1112.—Mispickel, Coolgardie.
T. 142.—Mispickel, Nova Scotia.

BARIUM.

This metal, which resembles calcium but is much more uncommon, was first separated early in the 19th century, though some of its compounds were known as far back as the 17th century. It is silver white, soft, and readily oxidises in the air. At ordinary temperatures it decomposes water with the evolution of hydrogen. At a dull red heat it melts.

Barium does not occur native. Its most important ore is the sulphate, barytes, which occurs either in veins in crystalline or other rocks or as boulders in residual clays resulting from the weathering of limestone. A less common though valuable ore is the carbonate, witherite, workable deposits of which occur as veins in limestone, etc.

Neither metallic barium nor alloys of it with other metals have any application in the arts. Pure artificial barium sulphate or blanc fixe is used for the same purposes as the mineral sulphate, *q.v.* It forms the chief constituent of "lithophone," a white paint which has largely replaced white lead for many purposes. The hydrate is extensively used to extract sugar from molasses, as

well as to make white paints and to soften boiler waters. Barium peroxide is used to prepare hydrogen peroxide and oxygenated water for bleaching, etc. The chloride is used in making paint as also the sulphide. This latter compound is also used to remove hair from hides, etc. The carbonate is used in manufacturing cyanides and fire bricks.

Barytes.—Sulphate of barium, $BaSO_4$. Baryta (barium oxide), 65 per cent. Crystallised, laminated, or granular massive. White or tinted, transparent to opaque. Brittle, soft. G., 4·5.

Uses.—After cleaning and grinding is added to white lead and zinc white. It is used in weighting and filling paper, making enamels and porcelain, in pyrotechny, and as a source of various barium compounds. The value of barytes depends upon its freedom from mechanically and chemically contained impurities, especially from iron compounds and other colouring materials.

204.—Massive Barytes, Northampton.

4451.—Crystallised Barytes, Oakover River.

Witherite.—Carbonate of barium, $BaCO_3$. Baryta, 77 per cent. Crystallised, massive, or globular. White, grey, or yellow, translucent. Soft, brittle. G., 4·3.

Uses.—An important source of all barium compounds, especially the peroxide.

BISMUTH.

This metal has been known to chemists for some centuries, though it is comparatively rare. It is a hard brittle metal of a dark reddish grey colour, and coarsely crystalline in structure when slowly cooled after fusion. It oxidises slowly in air at ordinary temperatures, more rapidly on heating. It dissolves readily in most mineral acids. Its specific gravity is between those of copper and silver.

Bismuth occurs in nature as the almost pure metal as well as the sulphide, bismuthinite, and the carbonate, bismutite. These are the only important ores, though bismuth also occurs as the oxide and telluride, and in several complex sulphides of lead and copper. Bismuth ores are found in veins of quartz or calcite, in slates, or crystalline rocks.

The market for bismuth ores is strictly limited, and is controlled by Messrs. Johnson, Matthey & Co., of London, and the Government of Saxony.

The metal bismuth is only employed in the form of alloys, many of which are of considerable value. Fusible metal is an alloy of bismuth, lead, and tin, and sometimes cadmium, which melts at a very low temperature, which can be varied by varying the relative proportions of the constituents. Owing to its expansion on solidification it gives a very perfect cast, and for this reason is used for stereotyping, making casts of woodcuts, etc. On account of its low and adjustable melting point it is used for safety plugs

for boilers, for automatic fire extinguishers, for baths, for tempering steel, and for solders. The pencils for writing on so called metallic paper are made of a bismuth alloy.

Bismuth oxide is used as a constituent of optical glass and of various glazes for porcelain and stained glass. Basic bismuth nitrate is largely used in medicine and also as a cosmetic. Several other bismuth compounds are used in medicine.

Bismuth (Native).—Pure bismuth, 94 to 99 per cent. Opaque metallic, reddish white to reddish grey. Foliated, massive or granular. Brittle, sectile. Very soft. G., 9·8.

Uses.—This is the chief source of bismuth and its compounds. Ore as low in grade as 5 per cent. is saleable, but it is more economical to handpick or otherwise dress the ore up to at least 25 per cent. before exporting. Gold and sometimes silver are constituents of native bismuth, and contribute largely to the value of the ore. The presence of tellurium in bismuth ore is a decided drawback, as it injures the qualities of the smelted metal.

2292.—Auriferous Bismuth in Quartz, Yalgoo. Ore assays bismuth, 2·6 per cent.; gold, 70·0 ozs. per ton; silver, 3·0 ozs. per ton.

Bismuthinite.—Sulphide of bismuth, Bi_2S_3. Bismuth, 81 per cent. Sometimes crystallised, usually foliated or fibrous massive. Metallic, opaque, lead grey. Very soft. G., 6·4.

Uses.—A less common ore of bismuth. (*See* remarks under Native Bismuth.)

T. 14.—Bismuthinite, Cornwall, England.

Bismutite.—Hydrated carbonate of bismuth. Bismuth, 80 per cent. Opaque, earthy, or in crusts. White, yellow, or greenish. Soft. G., 7·0.

Uses.—*See* remarks under Bismuthinite.

BORON.

This non-metallic element was first separated in the elemental state in 1808, but its most important compound, borax, has been known for several centuries. Boron is a light brown powder, very infusible, and a strong reducing agent.

Boron does not occur native. The most widely-distributed compound of it is tourmaline, a complex silicate of boron, aluminium, etc., frequently occurring as a constituent of granite. This mineral is, however, not a source of the commercial compounds of boron. These are derived from deposits of sassolite (boracic acid), borax (sodium borate), colemanite (calcium borate), and boracite (magnesium chloro-borate). Sassolite is obtained from hot springs; the other boron minerals are found in recent beds, usually in marshes or dry lakes in desert regions and in the neighbourhood of tourmaline-granites.

By far the most important compound of boron is borax, the uses of which are described under the native mineral. Boracic acid is also of considerable use as described under sassolite. The uncombined element has no application in the arts.

Sassolite.—Boracic acid, H_3BO_3. Boron trioxide 56 per cent. Scaly or stalactitic. White, transparent, or translucent. Very soft. G., 1·5. Occurs solid in volcanic regions, or dissolved in the waters of hot springs.

Uses.—The crude mineral is purified by crystallisation, and is then used as an antiseptic and food preservative as well as for sundry medicinal purposes.

Borax (Native).—Hydrous borate of sodium; boron trioxide, 37 per cent. Crystalline, white, brittle. Translucent to opaque. Soft. G., 1·7. Occurs as a crystalline efflorescence on the surface of dry lakes and in crystals embedded in the mud beneath them. Also in solution in waters of arid regions.

Uses.—The crude mineral is purified by recrystallisation and is then used as a food preservative and antiseptic, as a flux in many metallurgical operations, as a constituent of glass, artificial gems, enamels, and pottery-glazes, as a flux in welding and soldering, for softening water, and for various medicinal purposes.

Colemanite.—Hydrous borate of calcium. Boron trioxide, 51 per cent. Crystallised or massive. White, brilliant lustre, transparent to translucent. Hard. G., 2·4. Occurs in recent or ancient lake beds similarly to borax.

Uses.—An important source of boracic acid and borax. Value depends upon percentage of boron trioxide.

Boracite.—Chloro-borate of magnesium. Boron trioxide, 62 per cent. Crystallised or granular massive. White, translucent. Hard. G., 2·9. Occurs interbedded with salt and gypsum in ancient lake beds.

Uses.—A source of boracic acid and borax. Value depends upon percentage of boron trioxide.

CADMIUM.

This rare metal, discovered early in the 19th century, closely resembles zinc in appearance and properties, and is usually associated in nature with that metal. It is bluish white in colour, malleable and ductile. It tarnishes readily in the air, and at a high temperature burns. Its weight is the same as that of copper.

Cadmium does not occur native, but is known as a sulphide, greenockite. The chief sources of the metal are, however, cadmiferous varieties of the zinc ores blende and smithsonite, cadmium being obtained as a by-product in the smelting of such ores for zinc.

Metallic cadmium is used to a slight extent in analytical chemistry and as a constituent of certain fusible metals. An alloy

of silver and cadmium is used for plating purposes, for which it is found very advantageous. It has also been proposed to use the metal as a coating for battery terminals and connections. Cadmium sulphide is used as a pigment and in pyrotechny, and the iodide in photography.

Greenockite.—Sulphide of cadmium, CdS. Cadmium, 77 per cent. Crystallised, yellow, brilliant lustre, translucent. Brittle, soft. G., 5·0.

Uses.—A minor source of cadmium and its compounds.

Cadmiferous Blende.—Sulphide of zinc and cadmium (ZnCd)S. Cadmium up to 5 per cent. Resembles ordinary blende. *See* page 61.

Uses.—Chief source of cadmium, obtained as a bye-product in smelting for zinc.

4032.—Cadmiferous Blende, Northampton.

Cadmiferous Smithsonite.—Carbonate of zinc and cadmium, $(ZnCd)CO_3$. Cadmium, up to 3 per cent. Resembles ordinary smithsonite, *q.v.* page 61.

Uses.—A source of cadmium and its compounds.

CALCIUM.

Though compounds of calcium are amongst the commonest minerals on the earth's surface, and their properties have in many cases been known for centuries, the metal itself was only obtained in a state which permitted of handling and examination in 1856. It is a soft yellowish metal, somewhat stable in perfectly dry air, but readily converted into the oxide (lime) in moist air, and acted on by water with violence. It is one of the lightest metals known, being much lighter than aluminium.

Calcium does not occur in nature in the metallic state. Its commonest compound is the carbonate, calcite, which forms the chief constituent of all limestones, as well as of the shells of mollusca. In combination with silica, calcium forms a large proportion of many igneous rocks; the hydrated sulphate, gypsum, is of common occurrence. Phosphate of calcium forms the chief constituent of the bones of men and animals, as well as occurring as rock phosphate and in guano.

The metal itself has not as yet been put to any useful purposes. Its most useful artificial compound is the oxide, known as lime, formed by burning calcite in the form of limestone. Portland cement is a mixed silicate and aluminate of calcium formed by burning a natural or artificial mixture of calcite and clay. A very pure limestone on burning yields a fat or pure lime, one with a little clay yields a hydraulic lime, capable of setting under water, one with still more clay yields a hydraulic (or Portland) cement. Though the chief use of lime is for building, large quantities of it are also employed for other purposes, such as the preparation of bleaching powder (chloride of lime), ammonia, caustic soda, and

caustic potash, for purifying water, in cyanide works for neutralising acid, and for various other metallurgical purposes, as well as a fertiliser.

Sulphate of lime, produced by burning gypsum, is known as Plaster of Paris, and is employed either solely or with various added chemicals for finishing off the interior walls of buildings, as well as for making various mouldings and castings. "Superphosphate," a material largely used as a fertiliser, is a mixture of calcium sulphate and acid calcium phosphate, formed by acting on natural lime phosphates with sulphuric acid.

Chloride of lime or bleaching powder, used extensively for disinfecting and for bleaching, is a compound formed by allowing fat lime to absorb chlorine gas. Calcium carbide, now used to generate acetylene gas for lighting purposes, is a compound obtained by smelting together charcoal, or coke, and lime in an electric furnace.

Calcite.—Carbonate of calcium, $CaCO_3$. Lime, 56 per cent.; carbon dioxide, 44 per cent. Crystallised or massive, white, or tinted various colours, transparent or opaque. G., 2·7. Calcite forms rock masses under the names of *limestone* and *marble*.

Uses.—Chiefly used for burning into lime. To make the best lime for mortar or for use in preparing other calcium compounds or for other chemical purposes, the limestone should be practically free from silica, alumina, iron, and magnesia. For making Portland cement limestone should be free from iron, magnesia, and sulphur, but may with advantage contain silica and alumina equivalent to anything up to 25 per cent. of clay. A limestone containing in itself sufficient clay to form a Portland cement is known as a "*natural cement-rock.*"

Immense quantities of limestone are used for building purposes, for which the chief requisites are strength, freedom from pores, and capacity for resisting the weather.

Large quantities of limestone are used as a flux in smelting ore of iron, lead, copper, etc. For this purpose it is necessary that the stone should be rich in lime and low in silica (not more than 5 per cent.) and sulphur. Small proportions of iron and magnesia do not affect its value for this purpose.

The second constituent of calcite, viz., carbon dioxide or carbonic acid gas, is obtained from it by the action of suphuric acid, and is largely used in aerated water factories, etc. Any pure limestone is suitable for this purpose.

Perfectly transparent flawless crystals of calcite (Iceland Spar) are of considerable value for optical purposes.

2066.—Calcite Crystals, Coolgardie.

1015.—Crystalline Massive Calcite, Broad Arrow.

4471–73.—Stalactitic and stalagmitic Calcite, Blackboy Hollow Cave, Sussex District.

5371.—Calcite (Travertine), Leonora.

4431.—Limestone, Rottnest Island.

Dolomite.—Carbonate of calcium and magnesium (CaMg) CO_3. Lime, 30 per cent; carbon dioxide, 47 per cent. Similar to calcite, but slightly heavier. Forms rock-masses under the name of *magnesian limestone* or *dolomite*.

Uses.—With a natural or artificial admixture of clay, is burnt to form Rosendale hydraulic cement, for which purpose it should be low in iron and sulphur. Used in case of ordinary limestone as a flux, when the silica present should not exceed 5 per cent. Also used as a source of carbonic acid, for which purpose it is, if anything, more valuable than ordinary limestone. Large quantities are used as building stone. Sometimes used as a source of magnesia.

1988.—Crystallised Dolomite, Goongarrie.

5342.—Crystalline massive Dolomite, Porlelle.

Gypsum.—Hydrated sulphate of calcium, $CaSO_4 2H_2O$. Lime 32 per cent. Colourless, white or tinted; transparent to opaque; very soft. In large crystals, or crystalline masses, or as a fine crystalline powder. G., 2·3. Workable deposits occur in the beds of dry lakes or in sedimentary beds.

Uses.—Chiefly used in the manufacture of Plaster of Paris and various patent plasters. For this purpose it must be very pure and especially free from iron oxide, which would give the plaster an objectionable tint. It is used occasionally as a fertiliser, especially for grape vines. The massive variety, *alabaster*, is extensively carved into ornamental vases, etc.

5055.—Powdery Gypsum, near Cliffy Head, Victoria District.

1504.—Clear Crystallised Gypsum, Mingenew.

2360.—Fibrous Gypsum, Boulder.

Apatite.—Phosphate and chloride or fluoride of calcium, $3Ca_3P_2O_8Ca(FCl)_2$. Lime, 54 per cent.; phosphorus pentoxide, 41 per cent. Massive or crystallised; white or tinted; transparent to opaque; brittle, hard. G., 3·2. Payable deposits occur in veins and bunches in pyroxenite and other crystalline rocks.

Phosphorite or *Rock-phosphate* is an impure apatite occurring in irregular beds or nodules in limestone.

Guano, the earthy or hardened excreta of sea-birds, consists largely of macerated bones of fish, and therefore of impure calcium phosphate.

Uses.—The main use of apatite and similar compounds is as a fertiliser, either in the crude state or after conversion into "superphosphate." They are also used as a source of phosphorus, largely employed in the match industry, etc., and in the manufacture of white opaque glass. For these purposes the value of the ore depends upon the percentage of phosphorus pentoxide present. In addition to calcium phosphate, guano also contains ammonia and other nitrogen compounds, which add to its value as a fertiliser. Its value, therefore, depends primarily on the percentage of phosphorus pentoxide, next upon the percentage of nitrogen present. For use in the manufacture of superphosphate over 3 per cent. of oxides of

iron and alumina is looked upon as a serious drawback in any sample of rock phosphate or apatite; while the presence of a few per cent. of carbonate of lime is an advantage. For export, rock phosphate should contain not less than 65 per cent. of calcium phosphate; for local consumption, not less than 55 per cent.

5189.—Rock Phosphate, Clinton, S.A.

Fluorite (Fluorspar).—Fluoride of calcium, CaF_2. Calcium 51 per cent.; fluorine, 49 per cent. Crystallised, massive or granular. Transparent to translucent. Colourless or tinted various colours. Soft, brittle. G., 3·2. Occurs usually in veins in limestones and various crystalline rocks.

Uses.—Fluorspar is mainly used as a flux, in the open-hearth method of producing steel, and in remelting pig iron in foundries. It is frequently used to add to smelting mixtures not otherwise readily fusible, whilst it is said to assist materially in purifying crude copper. Smaller quantities are used in the production of opalescent glass and enamelled ware and of hydrofluoric acid. Fluorspar is occasionally cut into gems and ornaments. For use in steel production it should be free from sulphur and phosphorus, whilst for all purposes more than 1 per cent. of silica is a decided disadvantage.

CARBON.

Carbon is one of the commonest of the non-metallic elements, and numbers amongst its natural and artificial compounds many of the most useful substances known to civilisation.

It is known in three different modifications, diamond, graphite, and charcoal. Diamond is crystalline, colourless, transparent, and of high refractive index. It is harder than any other known substance, but somewhat brittle. Its specific gravity is 3·5. Graphite is crystalline, grey-black, opaque, with metallic lustre. It is very soft and smooth to the touch. Its specific gravity is 2·3. Charcoal in its purest form is a black amorphous powder, dull and opaque. It is variable in hardness and specific gravity, according to the method by which it has been formed.

Both of the crystalline forms of carbon, diamond, and graphite occur as minerals, but not so the amorphous form, unless possibly as a constituent of coals. The most important mineral compounds containing carbon are coal, petroleum, natural gas, and diamond, the first three of which owe their chief value to the ease with which they burn with the evolution of light, or heat, or both.

Diamond.—The purest forms of this mineral are dealt with under the heading "Gems," p. 67.

Bort and Carbonado.—Almost pure carbon of the diamond type. Grey or black, translucent to opaque. No distinct crystalline outline, usually in irregular water-worn grains. Extremely hard. G., 3·3. Occurs in river gravels.

Uses.—The chief use of these minerals is for setting in the crowns of rock-drills and the edges of lapidaries cutting wheels, and for polishing diamonds or other gems.

Graphite.—Almost pure carbon of the graphitic type. Sometimes in tabular crystals, more often in scales, or in scaly, columnar, or earthy masses. Black or dark grey, lustre usually metallic, sometimes dull; opaque. Very soft. G., 2·2. Occurs in beds or bands in metamorphic rocks, either gneiss, mica schist, quartzite, or crystalline limestone.

Uses.—The greater part of the world's production of graphite is used for mixing with fireclay to make crucibles for melting metals and alloys in. Smaller quantities are used for stove polish, foundry facings, paint, lubricating, lead pencils, and various electrical purposes. The purest forms of graphite are used for crucibles and lubricating. For these purposes the graphite should contain 95 per cent. of pure carbon, whilst for crucibles the ash should be infusible, and for lubricating, the mineral very flaky and greasy. Less pure varieties of the mineral can be used for the other purposes named, and command a correspondingly lesser price. Natural graphite has recently to a large extent been replaced by artificial graphite made from coke in the electric furnace.

3438.—Graphite. Oldfield River.

T. 17.—High-grade Graphite, Ceylon.

Coal.—This is a mixture of various compounds of carbon, hydrogen, oxygen, nitrogen, and sulphur, derived from the gradual alteration of buried vegetable matter. Five main types exist, viz., brown coal, non-caking bituminous, caking bituminous, anthracite, and algal coal.

Brown Coal.—Contains moisture 15 to 50 per cent.; ash, 1 to 35 per cent. Balance of coal contains carbon 55 to 71, hydrogen, 4 to 6, oxygen and nitrogen, 21 to 37. Ratio of fixed carbon to volatile hydrocarbons, 1 : 2 to 2 : 1. Brown and dull to black and bright. Sometimes with woody structure and then known as *Lignite*; when very bright and black, known as *Jet*.

Uses.—This is the poorest class of coal, and owing to the high percentage of moisture in it, it has to be sun-dried or artificially dried before use. The drying is frequently followed by compressing into briquettes. This coal is mainly used for household purposes, though it can also be used for steam-raising. The less ash and moisture in it the higher its calorific value, and therefore the more valuable it is.

623.—Brown Coal, Coolgardie.

2996.—Brown Coal, Fitzgerald River.

Non-caking Bituminous Coal.—Contains moisture, 5 to 15 per cent.; ash, 1 to 30 per cent. Balance of coal contains carbon, 70 to 85; hydrogen, 4 to 6; oxygen and nitrogen, 12 to 20. Ratio of fixed carbon to volatile hydrocarbons, 1 : 1 to 2 : 1. Bright or dull, black.

Uses.—A more useful type of coal than lignite, and can be used for all ordinary purposes such as steam-raising, gas-making, household use, tar-making, smelting, etc. It cannot be used for making coke, and is of small value for marine or locomotive engines.

5054.—Noncaking Bituminous Coal, Collie.
1994.—Noncaking Bituminous Coal, Collie.

Caking Bituminous Coal.—Contains moisture, 1 to 5 per cent.; ash, 1 to 30 per cent. Balance of coal contains carbon, 75 to 90 per cent.; hydrogen, 4 to 6; oxygen and nitrogen, 5 to 11. Ratio of fixed carbon to volatile hydrocarbons, 2 : 1 to 6 : 1. Bright or dull, black.

Uses.—The most useful of all kinds of coal. Suitable for household use, steam-raising under all conditions, coke-making, and gas, with accompanying production of ammonia, tar, cyanides, and numberless organic compounds. For steam raising its value depends upon the amount of heat generated in burning, freedom from ash, and infusibility of ash. For coking, its value depends upon quantity and hardness of coke and freedom from ash. For gas making, upon quantity and quality of gas given off on coking.

725.—Caking Bituminous Coal, Newcastle, N.S.W.

Anthracite.—Contains moisture ·5 to 2 per cent.; ash, 1 to 30 per cent. Balance of coal contains carbon, 90 to 96 per cent.; hydrogen, 2·5 to 4 per cent.; oxygen and nitrogen, 2 to 6 per cent. Ratio of fixed carbon to volatile hydrocarbons 6 : 1 to 10 : 1. Black, bright, hard. Not easily combustible, and does not form coke.

Uses.—This is the best coal for marine and locomotive purposes. Navies use it almost exclusively owing to its smokeless character and its high calorific value. It is also largely used for smelting and other purposes, but is useless for gas making. Its value depends upon the amount of heat generated in burning, freedom from ash, and infusibility of ash.

Algal Coal.—This includes *Kerosene Shale, Boghead Coal,* and *Torbanite,* all of which are largely composed of the *débris* of water plants. They contain moisture, 0·1 to 2 per cent.; ash, 1 to 40 per cent., graduating into an oil-shale as the ash increases. Balance of coal contains carbon, 78 to 80 per cent.; hydrogen, 12 to 14 per cent.; oxygen and nitrogen, 6 to 8 per cent. Ratio of fixed carbon to volatile hydrocarbons, 1 to 2 to 1 to 15. Dark brown; dull; tough; elastic. Catches fire readily and burns without melting.

Uses.—This coal is chiefly used to mix with bituminous coals for the production of illuminating gas. It is also distilled to yield oils (both illuminating and lubricating), paraffin wax, and ammonia. Its value depends upon the quantity and quality of its volatile products.

3123.—Kerosene Shale, Joadja, N.S.W.

Petroleum.—A natural liquid oil varying considerably in composition, but consisting mainly of a mixture of hydrocarbons of

the paraffin and naphthene series, the carbon varying from 79 to 87 per cent. Transparent to translucent; colourless, yellow, brown, or black. G., 0·7 to 1·0. Occurs in sedimentary deposits, in porous beds or cavities sealed by impervious beds of clay, etc., especially beneath anticlinal folds.

Uses.—Used extensively for steamers, locomotives, etc., in the crude state as fuel. Also distilled in large amounts, producing illuminating gas, light oils (gasolene, etc.), used for motors, etc.; illuminating oils (kerosene, etc.); heavy lubricating oils; vaseline or petroleum jelly, used as fuel, lubricant, etc.; paraffin wax, and sometimes asphalt or pitch. The most valuable petroleum is that which yields most illuminating oil, has the highest calorific value, and contains least sulphur. In America crude petroleum is used for watering the streets to keep down the dust, and is found far superior to water.

Natural Gas.—This contains from 93 to 97 per cent. of marsh gas or methane, the balance being nitrogen. It is the most perfect and convenient fuel known. 11 cubic feet giving approximately the same amount of heat on burning as a pound of good steam coal. It occurs in pores and cavities in sedimentary rocks of all ages, usually in association with petroleum.

Uses.—Largely used as a fuel for domestic and manufacturing purposes, its freedom from soot and ashes being a great advantage. It is used for melting steel, reheating iron, burning brick, steam-raising, etc.

Asphaltum.—A mixture of various hyhrocarbons partly oxygenated and invariably carrying sulphur. Analyses usually show the presence of ash, non-bituminous organic matter, petrolene, and asphaltene, all in varying quantities. Amphorous, solid, or semi fluid. Black or dark brown, opaque. Melts and burns readily. G., 1 to 1·8. Occurs in surface beds or disseminated through sandstones or limestones. Usually closely associated with petroleum.

Uses.—The chief use of asphalt is as a binding material for crushed rock, etc., for roadways, footpaths, and foundations, damp courses in houses; as a protective covering for wood or iron; as an ingredient of roofing felt; as an ingredient of various varnishes and japans. For street paving the asphalt may be already naturally mixed with the necessary quantity of rock. Otherwise the less ash the better, whilst the proportion of non-bituminous organic matter should not exceed 15 per cent. of the total organic matter, and the proportion of petrolene should exceed that of asphaltene. The purest varieties only of asphalt can be used for making varnishes. These should be hard, have a very bright lustre and pure black colour, and be practically free from ash and non-bituminous organic matter.

3429.—Drift Asphaltum, Warren River, Nelson District
4448.—Drift Asphaltum, Doubtful Island Bay, Kent District.

Ozokerite.—Mixture of solid hydrocarbons of the paraffin series. Amorphous, wax-like. White, yellow, or brown; translucent. G., 0·9. Occurs in veins or irregular deposits in sedimentary beds in association with asphaltum and petroleum.

Uses.—Chiefly used as a source of mineral wax or cerasin, the applications of which are numerous, such as making candles, waxed paper, adulterating beeswax, etc. For this purpose its value depends upon the percentage yield of purified white wax. Also used as a source of illuminating gas, oils, etc.

CERIUM.

This rare metal was discovered in 1803. It is a soft, grey, ductile metal, which burns readily in air like magnesium. It is a little lighter in weight than iron, and like that metal is not readily affected by dry air, but is susceptible to moist air. The metal itself has no application in the arts.

Cerium does not occur free in nature, but, together with several other similar rare metals, occurs as a constituent of certain silicates and phosphates occurring sporadically in crystalline rocks, especially granite and gneiss, and in the heavier sands derived from their degradation. It is the latter which form the chief sources of the metal.

The most important compound of cerium is the dioxide which forms a small proportion of the Welsbach incandescent mantle and the glower of the Nernst lamp, this oxide having the property, possessed in a still higher degree by the oxide of thorium, of glowing with an intense light when heated. Cerium nitrate is prepared largely for use in the manufacture of the Welsbach mantles. Both this salt and cerium oxalate are used to a slight extent in medicine.

Monazite.—Phosphate of cerium, lanthanum, and didymium $(Ce,La,Di)PO_4$. Cerium oxide, 16 = 37 per cent. This is the commonest cerium mineral, but as its value depends almost entirely upon the small and variable proportion of thorium oxide contained in it, it will be treated fully under Thorium, page 52.

5437.—Monazite Sand, North Carolina, U.S.A.

Cerite.—Hydrous silicate of cerium, lanthanum, didymium, iron and lime. Cerium oxide, 25 = 65 per cent. Brown or grey; opaque; as hard as felspar; brittle; no definite cleavage. G., 4·9.

Uses.—Used as a source of salts of cerium.

Allanite (Orthite).—Complex silicate of cerium, lanthanum didymium, aluminium, iron, and calcium. Cerium oxide 2-18 per cent. In tabular or acicular crystals or massive. Black, brown, green, grey, or yellow opaque; hard; brittle. G., 4·0.

Uses.—Used as a source of salts of cerium.

CHROMIUM.

This metal was discovered at the end of the 18th century, but is still, in its pure form, only of scientific interest. It is a very hard and infusible metal, of a white colour, and of the same weight as cast iron. It is not easily affected by the atmosphere.

Chromium does not occur in nature in the metallic state, but, in combination with silica, occurs in small quantities in all igneous rocks. It is found at times in lead lodes in the form of crocoite, a yellow chromate of lead. The only workable ore of chromium is chromite, which is invariably found as scattered grains, pockets, or veins in the basic igneous rocks known as peridotite and serpentine. Turkey and New Caledonia are the most important source of chrome ore.

Pure metallic chromium is not produced commercially, but impure chromium and an alloy of chromium and iron, ferro-chromium, obtained by smelting chromite, are largely used as constituents of hard steel for rails, machine tools, safes, projectiles, and the wearing parts of crushing machinery.

The most important manufactured compounds of chromium are the chromates and bichromates of potash and soda, which are extensively used for tanning and dyeing, and to a minor extent in the manufacture of matches, in generating electricity, and in purifying oils and spirits. Chromium sesquioxide is used as a pigment. Chrome alum, sulphate of chromium and potash, is used in dyeing, calico printing, and tanning, and also in rendering gum and glue insoluble for water-proofing.

Chromite or Chrome Iron Ore.—Chromite of iron $FeOCr_2O_3$. Chromium, 47 per cent.; chromium sesquioxide, 68 per cent. Sometimes crystallised; usually massive, granular, or compact. Black, opaque, massive. Lustre, metallic to glassy; hard; brittle. G., 4·4.

Uses.—Extensively used for the manufacture of chromates and other salts, and for smelting into ferrochromium. Within the last few years a new use has been found for the mineral in its raw state, namely, as a lining for reverberatory copper and steel smelting furnaces, the life of which is thereby increased two or three-fold. Already the demand for this purpose has reached important proportions. A still later use is in the production of "Silichromite," a material used as a substitute for emery. The commercial value of chrome ore depends almost entirely upon the percentage of chromium sesquioxide present in it, ore under 50 per cent. being marketed with difficulty. The usual market grade is from 50 to 55 per cent., up to which standard the ore is concentrated by hand picking or jigging. For furnace lining the ore should be in fair sized lumps with little or no dust.

1758.—Chromite, Gobarralong, N.S.W. High grade ore.

1759.—Chromite, Gobarralong, N.S.W. Low grade ore.

1760.—Chromite in Serpentine matrix, Gobarralong, N.S.W.

COBALT.

Cobalt is a somewhat rare metal which has been known for about a century and a-half, but for which very few uses have been found. It is a bluish-white hard metal, which takes a good polish, unaffected by the air. It is magnetic, malleable, and, when hot, very ductile. Its weight is about that of copper.

Cobalt does not occur in nature in the metallic state. Its chief ore is asbolite, an oxide of manganese and cobalt. It is also frequently found as the arsenide, smaltite, and sulpharsenide, cobaltite. More or less cobalt occurs in most nickel ores, and in most cases is recovered as a bye-product. Cobalt occurs in many other minerals which, however, owing to their rarity, do not constitute ores of the metal. Descriptions will be found in any text book of Mineralogy.

Metallic cobalt is only used for electroplating, and for that but rarely, though it is said to be superior to nickel for that purpose. Black oxide of cobalt is used in the preparation of sundry pigments, principally smalt but also cobalt blue, green, yellow, and violet-bronze. Smalt is commercially the most important artificial compound of cobalt. It is a silicate of this metal and potassium having a very fine and permanent blue colour. It is used for bluing paper, linen, and starch, and for colouring and painting on glass and porcelain and for enamels. Cobalt nitrate is used as a chemical re-agent and for making invisible inks.

Asbolite.—Hydrous oxide of manganese and cobalt. Cobalt oxide, 1 to 32 per cent.; nickel, trace to 10 per cent.; manganese dioxide, 50 to 70 per cent. Black or dark-grey, opaque, massive, or stalactitic. Very soft to hard. G., 4·0. Usually occurs in irregular masses amongst the decomposition products of basic igneous rocks.

Uses.—The chief source of cobalt and its compounds. Its value is enhanced by the presence of a high percentage of manganese dioxide, since the ore can then be used for the production of chlorine and the cobalt and nickel subsequently recovered from the liquors. For export, ore should be dressed to at least 4 per cent. by washing, to remove some of the associated clay. Nickel in small proportions depreciates the value of the ore, in larger proportions enhances it.

1577.—Asbolite in Clay, Kanowna.

1801.—Asbolite, Boulder.

2956.—Asbolite, Kalgoorlie.

Smaltite.—Arsenide of cobalt, $CoAs_2$. Cobalt, 8 to 24 per cent.; nickel, trace to 8 per cent. Crystallised or massive. Metallic, white to grey, often tarnished. Hard; brittle. G., 6·5. Occurs in veins of quartz, etc.

Uses.—A minor source of cobalt (and nickel).

T. 114.—Smaltite, Cornwall, England.

Cobaltite.—Sulpharsenide of cobalt, CoAsS. Cobalt, 9 to 34 per cent.; nickel, trace to 8 per cent. Crystallised or massive. Metallic, white, reddish, grey. Hard, brittle. G., 6·1.

Uses.—A minor source of cobalt and its compounds.

T. 116.—Massive Cobaltite, St. Just, England.

T. 117.—Crystallised Cobaltite, Tunaberg, Sweden.

COPPER.

Copper is one of the few metals that has been known to man and utilised by him since prehistoric times. This is partly because it is somewhat frequently found native, and partly because its surface ores are readily reduced to the metal by smelting.

Copper is a very tough red metal, highly ductile and malleable. It is, after silver, the best known conductor of electricity and heat. It is not readily attacked by air or water. Its specific gravity is 8·9.

As already stated, metallic copper occurs native in many parts of the world, especially on the shores of Lake Superior. It also occurs as an important constituent of a vast number of mineral compounds, only a few, however, of which occur in large deposits. These are the two oxides, cuprite and tenorite; the two hydrated carbonates, malachite and azurite; the simple sulphides, chalcocite and covellite; the sulphides of copper and iron, chalcopyrite and bornite; and, finally, fahl-ore or tetrahedrite, a sulphide of copper, antimony, and arsenic.

Ores of copper are chiefly found in veins or lodes in crystalline rocks, slates, and sandstones; but also as impregnations in sedimentary beds, volcanic ash, etc.

Electrolytic refining is now carried out with such success that commercial copper contains less than one-tenth of one per cent. of impurities. Its chief uses are in making wire for electric conductors, and in making alloys. Smaller quantities of the metal are used for a multitude of purposes, including the manufacture of various utensils and apparatus, boiler tubes, nails, sheet-copper for roofing, battery plates, pile-sheathing, and ship-sheathing, etc.

The most important alloy of copper is brass, a variable mixture of copper and zinc, one variety of which, known as muntz-metal, is extensively used for sheathing ships and piles. Copper is also the main constituent of bronze, gun-metal, aluminium bronze, and German silver. Copper is invariably added to gold and silver in coinage, jewellery, and plate to harden them.

Of artificial compounds of copper, the most important is bluestone (copper sulphate) used in extracting silver from its ores, in generating electricity, in dyeing and printing, as an insecticide, etc. Several compounds of copper are used as pigments, yielding various shades of green, blue, and purple.

Copper (Native).—Practically pure copper with traces only of silver, bismuth, etc. In crystalline or irregular masses often coated with curite or malachite. Red, opaque, metallic. Soft, tough, malleable G., 8·9.

Uses.—An nportant source of commercial copper.

1167.—Naive Copper, Geraldine.

Cuprite.—Red oxide of copper, Cu_2O. Copper, 88 per cent. Crystalline, masive or granular. Bright or dark red, translucent or opaque. Sof, brittle. G., 6·0.

Tile Ore.—A massive red variety of cuprite, containing oxide of iron intimatel mixed with it. Copper, 50 to 80 per cent.

Uses.—An nportant ore of copper. The value of this ore, as of all others, deends primarily upon the percentage of copper present; secondl, upon the quantity of associated silver and gold; thirdly, upon thenature of the accompanying impurities and gangue. Of impurities bimuth is the most objectionable, and arsenic and antimony next. Other things being equal, that ore is the most valuable the ganue of which contains such a proportion of silica, lime, and iron oxde as to be self-fluxing or nearly so.

T. 58.—Cprite, Cornwall, England.
5303.—Curite, Ravensthorpe.
1617.—Til Ore, Croydon, W. Pilbarra G.F.

Tenorite.—Black oxide of copper, CuO, frequently mixed intimately with more or less chalcocite (CuS). Copper, 80 per cent. Scaly, masive, or earthy. Black, metallic or dull. Soft. G., 6·0.

Uses.—*See* Cuprite.

1816.—Tenorite, Rothesay.

Malachite—Hydrated carbonate of copper. Copper, 57 per cent. Crystallised or, more commonly, massive, stalactitic, radially fibrous, or earthy Bright green, opaque. Soft, brittle. G., 4·0.

Uses.—*See* Cuprite. Some varieties are sufficiently beautiful when cut and poshed to be used for inlaying and other ornamental work.

3707.—Fibous Malachite, Whim Creek.
1506.—Masive Malachite, Whim Creek.
2507.—Machite Stockwork in sandstone, Arrino.

Azurite.—Hydrated carbonate of copper. Copper, 55 per cent. Crystallin, massive, compact, or earthy. Azure-blue, transparent to opaque Soft, brittle. G., 3·8.

Uses.—*See* Cuprite.

4025.—Crystallised Azurite, Northampton.
4011.—Azurite, Narra Tarra.

Chalcocite.—Black sulphide of copper, Cu_2S. Copper, 80 per cent. Crystallised, massive, compact, or granular. Black, metallic, opaque. Soft, brittle. G., 5·7.

Uses.—*See* Cuprite.

2352.—Massive Chalcocite, Murrin Murrin.

3792.—Massive Chalcocite, Arrino.

Covellite.—Indigo sulphide of copper, CuS. Copper, 66 per cent. Crystallised or massive. Indigo-blue, subnetallic, or dull, opaque. Very soft and brittle. G., 4·6.

Uses.—*See* Cuprite.

Chalcopyrite (Copper pyrites).—Sulphide of copper and iron, $CuFeS_2$. Copper, 34 per cent. Crystalised or massive. Brass-yellow, metallic, opaque. Sometimes tarnished or iridescent. Soft, brittle. G., 4·2.

Uses.—*See* Cuprite.

1814.—Chalcopyrite, Rothesay.

4033.—Chalcopyrite, Northampton.

Bornite.—Sulphide of copper and iron, Cu_3FeS_3. Copper, 55 per cent. Often intimately mixed with chalcopyrite or chalcocite, the copper contents then varying from 50 to 70 per cent. Crystallised, or massive, granular or compact. Usually iridescent. On fresh fracture copper-red to brown, but rapidly tarnishing. Metallic, opaque. Soft, brittle. G., 5·2.

Uses.—*See* Cuprite.

T. 52.—Bornite, South Australia.

Tetrahedrite (Fahl-ore). — Sulphide of copper and antimony, with variable amounts of arsenic, bismuth, iron, zinc, lead, silver, or mercury. Copper, 15 to 44 per cent.; silver, strong trace to 31 per cent. Crystallised or massive, compact or granular. Grey to black, metallic, brilliant, opaque. Soft, brittle. G., 4·7.

Uses.—*See* Cuprite. A very valuable ore owing to the constant presence of a notable amount of silver, which usually more than compensates for the presence of such objectionable constituents as bismuth, arsenic, and antimony.

5548.—Tetrahedrite, Ravensthorpe Range.

GOLD.

From the very earliest times gold has been known and valued for its great beauty. When pure it is a very soft yellow metal susceptible of a brilliant polish and untarnished by exposure to air, water, or most chemicals. It is the most malleable and ductile of all metals, as well as one of the heaviest, its specific gravity being 19·3.

Gold is but rarely found in nature in a state of great purity, the so called native gold being an alloy of this metal with more or less silver, seldom containing more than 95 per cent. of the pure metal.

This alloy is by far the most common source of the metal. Gold also occurs in nature alloyed with mercury as native amalgam, and in combination with tellurium and silver in various telluride ores, chiefly calaverite, sylvanite, and petzite. Gold also occurs in minute invisible specks scattered through many samples of pyrites, copper ores, etc., and can frequently be extracted from these ores at a profit owing to the great value of the metal and the high pitch of perfection to which its metallurgy has attained.

Native gold occurs in veins or lodes, or disseminations in crystalline and other rocks, as well as in alluvial deposits, river gravels, etc. The telluride ores occur only in veins or lodes below the zone of complete oxidation.

Pure gold is chiefly used as a surface covering or plating to ornaments and utensils of other metals. It is also used extensively for stopping teeth. When beaten out into leaf it is used for ornamental painting and lettering. For other purposes gold is hardened by being alloyed with copper or silver or both, such alloys being used for coinage, jewellery, plate, etc. The most useful artificial compound of gold is the chloride, which is used in photography and in the manufacture of ruby glass. Purple of Cassius is a compound containing gold and tin, and is used in making ruby glass.

Gold (Native).—Gold alloyed with more or less silver. Gold 50 per cent. to 99 per cent.; silver, trace to 50 per cent. Varieties containing over 30 per cent. of silver are known as *Electrum*. Crystallised, dendritic, massive, granular, spongy, in flakes, and in rolled grains and nuggets. Opaque, metallic, yellow of various shades. Soft, malleable. G., 14 to 19.

Uses—The chief source of gold and its compounds.

3696.—**Crystallised Gold in Asbolite, Kanowna.**
1238.—**Dendritic Gold, Donnybrook.**
419.—**Massive Gold, Peak Hill.**
3712.—**Granular Gold, Boogardie.**
1503.—**Sponge Gold, Boulder.**
2499.—**Flake Gold, Kalgoorlie.**
1915.—**Alluvial Gold, Greenbushes.**

Calaverte.—Telluride of gold, $AuTe_2$. Gold, 34 to 42 per cent.; silver 0·5 to 5 per cent. Massive, metallic, brilliant. White to yellow, opaque. Soft, brittle. G., 9·2.

Uses—A source of gold and its compounds.

144.—**Calaverite, Boulder.**

Krennerite.—Telluride of gold and silver. $(AuAg)Te_2$. Gold, 34 to 3 per cent.; silver, 3 to 6 per cent. Crystallised, with perfect cleavage. White to yellow, metallic, brilliant, opaque. Soft, brittle. G., 8·2.

Uses.—A source of gold and silver and their compounds.

87.—**Krennerite, Boulder.**

Sylvanite.—Telluride of gold and silver. $(AuAg)Te_2$. Gold, 26 to 30 per cent.; silver, 8 to 18 per cent. Crystallised, arborescent, beaded or massive, with a perfect cleavage. White, grey, or yellow. Metallic, brilliant, opaque. Very soft, brittle. G., 8·1.

Uses.—A source of gold and silver and their compounds.

Petzite.—Telluride of gold and silver $(AgAu)_2Te$. Gold, 18 to 26 per cent.; silver, 40 to 47 per cent. Massive, granular, or compact. Black, metallic, brilliant, opaque. Soft. G., 8·9.

Uses.—A source of gold and silver and their compounds.

1806.—Petzite, Boulder.

Nagyagite.—Sulphotelluride of gold, lead, and antimony. Gold, 6 to 13 per cent.; silver trace to 2 per cent. In tabular crystals with perfect cleavage, and massive, granular, or foliated. Lead-grey, metallic, brilliant, opaque. Very soft. G., 7·0.

Uses.—A rare source of gold and silver and their compounds.

IRON.

Of all the metals that have been pressed into the service of man, iron is by far the most common and most useful, and was first utilised in prehistoric times. The chemically pure metal is not an article of commerce. It is a white metal capable of taking a high polish. It is somewhat harder than copper, and considerably stronger; it is malleable, and at a red heat can be welded. Iron can only be melted at a dazzling white heat; when heated somewhat and cooled suddenly it does not harden. Iron does not tarnish in perfectly dry air, but in moist air or water rapidly rusts. Salt water and weak acids attack it rapidly.

Iron appears in commerce in three states of varying purity, known respectively as wrought iron, steel, and cast iron. All these forms of iron contain as impurities carbon, silicon, phosphorus, sulphur, and manganese, and it is upon the relative proportions present of these elements, especially carbon, that the quality of the metal depends. Wrought iron is the purest form of commercial iron, and contains essentially from ·03 to ·40 per cent. of carbon. It closely resembles pure iron in its properties, but is slightly more fusible and less malleable than the latter. Steel contains, in addition to the usual impurities of all forms of iron, an amount of carbon varying from ·4 per cent. to 1·5 per cent. It differs from wrought iron in being less malleable and less easily welded, more fusible, and stronger. Its most striking feature is its capacity for becoming extremely hard when heated and suddenly chilled. Cast iron contains from 1·5 to 5 per cent. of carbon and comparatively large quantities of sulphur, phosphorus, and silicon. It melts more easily than steel, is brittle when cold, and does not harden on heating and quenching.

Iron occurs in abundance in nature in many forms (very rarely as the metal), being an important constituent of almost all rocks.

The only native compounds, however, that can be profitably employed as a source of the metal are the oxides, magnetite, etc., and the carbonate, siderite.

Pure iron, as already stated, is not used in the arts; the purest wire used for piano strings, etc., still containing 0·3 per cent. of impurities. Wrought iron is used for a multitude of purposes, chiefly for forged parts of machinery, boiler plates, pipes for water, gas, etc., girders and other structural members, roofs, etc. Steel has largely replaced wrought iron for many purposes. Its chief uses are for rails, tools, bridges, parts of machinery, and structures of various kinds, [illegible] Cast iron is made mainly as an intermediate product in the manufacture of steel and wrought iron. It is also largely used for casting various machine details and industrial and domestic utensils.

The chief alloys of iron are those varieties of steel containing various proportions of manganese, nickel, and rarer metals. These are for the most part harder and stronger than ordinary steel. Various cast alloys of iron with manganese and other metals are produced solely for the production of the special steels above mentioned. Chief of these are spiegel and ferro-manganese, alloys of manganese and iron with considerable carbon, used in the manufacture of Bessemer steel, Hadfield's manganese steel, etc.

Compared with the metal itself, the artificial compounds of iron are of minor importance. Artificial ferric oxide is employed as a pigment and polishing powder (rough). The hydrate, carbonate, and other salts are used in medicine. An artificial mixture of the oxides (iron-scale) is used in the conversion of cast iron into wrought iron and steel. Ferrous sulphate (copperas) is used to precipitate gold, and in the manufacture of Nordhausen sulphuric acid, iron mordants, inks, etc. Prussian blue, a cyanide, is a valuable pigment. Potassium ferrocyanide is used as a source of potassium cyanide and as a chemical re-agent.

Magnetite.—Magnetic oxide of iron, Fe_3O_4. Iron, 65 to 72 per cent. Crystalised or massive, granular or compact. Black, metallic, opaque. Magnetic, hard, brittle. G., 5·1. Occurs as irregular masses in volcanic rocks, and as lodes in schists.

Uses.—The richest and purest ore of iron, used largely for the production of the commercial metal, and to a slight extent as a flux in lead and copper smelting. Bulk samples of ore contain various impurities, which mostly exert a marked effect upon the final smelted metal, and, hence, influence to a very large extent the value of a deposit. The chief of these are phosphorus, sulphur, silica, and titanic oxide.

Phosphorus.—This element, in more than traces, is the most objectionable constituent of an iron ore. Ores containing more than ·045 per cent. of phosphorus are practically useless for the production of Bessemer steel. Basic steel (Thomas steel) can be made most profitably from ores containing from 0·4 to 2·0 per cent. phosphorous. Intermediate ores are best suited for the production

of wrought iron, and grey and white iron for castings. With ores rich in iron a slightly higher percentage of phosphorus is permissible than with poor ores.

Sulphur.—This element is not so objectionable as phosphorus. The best ores contain less than 0·05 per cent. of this element. Inferior ores contain up to 2·0 per cent., and are frequently roasted to remove this sulphur before smelting.

Silica.—Small amounts of this under 5 per cent. are no drawback to the ore, beyond that amount the less the better since the more silica contained in the ore the more lime needed to flux it. If the ore contains lime or alumina this will serve to neutralise the bad effect of an increased content of silica. For iron smelting the best ores contain not more than 10 per cent., poorer ores 10 to 30 per cent. For fluxing lead or copper ores the silica must not exceed 7 per cent.

Titanic Oxide.—This constituent is usually stated to cause considerable difficulty in the smelting of pig-iron, and most iron smelters look askance at ores containing more than 0·5 per cent. Lump ores, however, containing up to 40 per cent. TiO_2 have been smelted in both England and the United States without causing any difficulty, so that apart from the concurrent decrease in the iron content the presence of a notable percentage of titanium can only be considered a drawback by prejudiced persons, so long as the ore is massive and not in the state of fine sand. In fluxing lead and copper ores titanic oxide acts like silica, and the total of these two constituents should not therefore exceed 7 per cent., whilst the titanic oxide alone should be under 5.

Other Constituents.—Manganese oxide in small quantities increases the value of an iron ore for all purposes. Lime and alumina to the extent required for fluxing the silica of the ore are also an advantage.

5545.—Magnetite Crystals, Eastern Goldfields.
784.—Magnetite (Granular Massive), Collie.

Hæmatite.—Oxide of iron, Fe_2O_3. Iron, 67 to 70 per cent. Crystallised, massive granular, columnar or stalactitic, earthy, micaceous. Earthy variety red, soft to hard, dull, opaque. Other varieties black, metallic, hard, opaque, brittle. G. 5·1.

Uses.—An important source of iron. (*See* remarks under Magnetite.)

T. 145.—Crystallised Hæmatite, Elba.
5356.—Granular massive Hæmatite, Wilgi Mia, Weld Ranges.
4359.—Massive Hæmatite, near Mullewa.
48.—Micaceous Hæmatite, Boulder.

Limonite.—Hydrated oxide of iron, $2Fe_2O_3.3H_2O$. Iron, 57 to 60 per cent. Stalactitic, fibrous, concretionary, massive or earthy. Brown or yellow, sometimes iridescent, opaque. Soft or hard. Brittle.

The *Laterite Ore* (surface clay ironstone) of Australia and India is a mixture of limonite with more or less bauxite (aluminium ore) and sometimes some hæmatite, gothite, or other hydrated oxides of iron. It is concretionary or cellular, massive, and contains up to 62 per cent. of iron.

Uses.—An important source of iron. (*See* remarks under Magnetite.)

The soft earthy yellow varieties known as *Ochre* contain more or less clay and are used largely for the production of pigments and giving a body to linoleum or oilcloth. For this purpose the value of the ore depends upon the fineness of its grain, its freedom from grit and its colour both fresh and when calcined.

Concretionary limonites and laterites are largely used for ballasting roads and railways.

1408.—**Massive Limonite, Greenhills.**
101.—**Fibrous Limonite, Mt. Jackson.**
498.—**Limonite stalactite, Mt. Morgan, Queensland.**
996.—**Limonite (Laterite), Wongan Hills.**
T. 166.—**Limonite (Yellow Ochre), South Australia.**

Siderite (Spathic iron ore).—Carbonate of iron, $FeCO_3$. Iron, 40 to 48 per cent. Crystallised, massive granular, fibrous, compact, earthy. Grey, yellow, or brown, translucent to opaque. Soft, brittle. G., 3·8.

The *Clay-band Ironstone* of England is an impure siderite containing much clay. The *Black-band Ironstone* of Great Britain and America is a siderite mixed with much coaly matter.

Uses.—An important ore of iron. (*See* remarks under Magnetite.)

T. 183.—**Siderite, West Prussia.**
T. 186.—**Clay-band Ironstone, Staffordshire, England.**

Franklinite.—Oxide of iron, zinc, and manganese. Iron, 40 to 60 per cent.; manganese, 8 to 18 per cent.; zinc, 5 to 18 per cent. Crystallised, massive, granular, or compact. Black, opaque, metallic or dull. Hard, brittle, slightly magnetic. G., 5·1.

Uses.—After recovering the zinc the residue is smelted with the production of ferro-manganese. For impurities and their effects see under Magnetite.

T. 156.—**Franklinite, New Jersey, U.S.A.**

Ilmenite (Titaniferous Iron Ore).—Oxide of iron and titanium, $FeO.TiO_2$. Iron, 36 to 60 per cent.; titanium, 6 to 31 per cent. Crystallised, massive, in scales or rolled grains. Black metallic, opaque. Hard, brittle. G., 4·7. Occurs largely as beds of black sand on beaches, etc., also mixed with magnetite in irregular masses and lodes in basic igneous rocks.

Uses.—Used as a source of iron, ferro-titanium, and titanium compounds. The fine sandy ore has not yet been successfully

smelted for iron on a large scale. After grinding it is sometimes used as a knife polish and as a pigment for covering metal work.

T. 205.—Massive Ilmenite, Mt. Barker.

5366.—Ilmenite Sand, Bunbury.

Chromite (*see* page 26) is used as a source of ferro-chromium; and **Wolfram** (*see* page 56) as a source of ferro-tungsten.

LEAD.

This was one of the few metals known to man in very ancient times. It is a very soft bluish white metal, which can be readily rolled or pressed into sheet or wire. It rapidly tarnishes on exposure to the air and is then but little affected by air or many acids. It melts below a red heat and has a specific gravity of 11·3.

Occasional grains of metallic lead have been found in nature, but it chiefly occurs as the sulphide, galena. A second common ore is the carbonate, cerussite, whilst much less common are the sulphate, anglesite, and the chlorophosphate, pyromorphite. Ores of lead usually occur in veins and lodes in crystalline rocks, slates and limestones.

Commercial lead is extremely pure and is largely used in sheets for roofing and making pipes. It is also used for bullets and for making white lead, red lead, litharge, etc. Lead hardened with a few per cent. of antimony is used for coffins and for lining acid chambers, etc. Of lead alloys the most important is that with tin, known as solder, and that with tin and antimony, known as type metal. Fusible alloys and antifriction alloys contain a large proportion of lead.

Of the artificial compounds of lead, by far the most important is white lead, a basic carbonate, which is the most useful pigment known. Red lead, an oxide, is also a valuable pigment, and is used in the manufacture of flint glass. Litharge, another oxide, is used as pigment, as a constituent of many varieties of glass and of glazes for clay-ware, and in manufacturing white lead. Lead chromate is used as a pigment, as also lead sulphate.

Lead ores are used almost solely as a source of the metal from which, after refining, the various artificial compounds are prepared. Two other minor, though still important, uses they are put to. One is in the metallurgy of the precious metals, the ores of these being smelted with ores of lead, to form the so-called base bullion, or pig lead containing all the gold and silver in solution in a convenient concentrated form for final recovery. The second use is in the production of lead fume, a fine mixture of lead sulphate and oxide used as a pigment.

Galena.—Sulphide of lead, PbS. Lead, 83 to 86 per cent.; silver, trace to 3 per cent. Crystallised with cubic cleavage or granular massive. Lead grey, metallic, opaque. Soft, brittle. G., 7·5.

Uses.—The main source of metallic lead. Also used as a source of lead fume and in recovering gold and silver from their ores. The value of the ore depends upon the amount of lead and silver present. The best bulk ores contain less than 5 per cent. of zinc, as this metal causes trouble in smelting, and not more than a trace of antimony and arsenic.

4002.—Crystallised Galena, Narra Tarra.

1524.—Galena, Andover.

Cerussite.—Carbonate of lead, $PbCO_3$. Lead, 77 per cent.; silver, traces. Crystallised or granular or compact massive. White or grey, transparent to opaque. Soft, very brittle. G., 6·5.

Uses.—An important ore of lead. On value, *see* remarks under Galena.

T. 83.—Crystallised Cerussite, Cumberland, England.

4007.—Massive Cerussite, Narra Tarra.

Anglesite.—Sulphate of lead, $PbSO_4$. Lead, 66 to 68 per cent.; silver, traces. Crystallised or massive, granular compact or stalactitic. White or tinted, transparent to opaque. Soft, very brittle. G., 6·2.

Uses.—A common ore of lead. On value, *see* remarks under Galena.

411.—Anglesite with Galena, Gorge Creek.

Pyromorphite.—Chlorophosphate of lead. Lead, 62 to 75 per cent.; silver, traces. Crystallised or massive, resinous. Green, yellow or brown, translucent or opaque. Soft, brittle. G., 6 to 7.

Uses.—A minor ore of lead.

1168.—Crystallised Pyromorphite, Geraldine.

33.—Massive Pyromorphite, Narra Tarra.

LITHIUM.

Lithium is one of the alkali metals closely resembling sodium, but of much greater rarity, and was discovered in 1817. It is silver white, softer than lead and extremely light, being only a little over half as heavy as water. It melts at a low temperature and if heated much beyond that point burns steadily with a bright white light. It rapidly tarnishes when exposed to the air.

Lithium does not occur in nature in the metallic state but usually in combination with other metals and silica in granite or in pegmatite veins or dykes.

The metal is not put to any use in the arts. Its most important artificial compounds are the chloride, carbonate, and citrate, all of which are used for medicinal purposes and also as contituents of aerated waters (lithia water, etc.).

Lepidolite (Lithia mica.)—Fluosilicate of lithium, aluminium, and potassium. Lithia (lithium oxide), 4 to 6 per cent.

In scaly granular masses or in large cleavable plates. Pink, amethystine, white, or grey. Transparent or translucent. Soft, tough. G., 2·8.

Uses.—This is the chief source from which lithium salts are prepared, and its value will depend upon the proportion of lithia present in it.

1858.—Lepidolite in radiating scales, Coconarup.

556.—Lepidolite, in large sheets, Londonderry.

Spodumene. — Silicate of lithium and aluminium, $Li_2O.Al_2O_3.4\ SiO_2$. Lithia, $4\frac{1}{2}$ to $7\frac{1}{3}$ per cent. Crystallised or massive, vertical cleavage well marked. Green, sometimes yellow or purple. Transparent to opaque. Hard and brittle. G., 3·2.

Uses.—Same as for lepidolite, which see.

1864.—Spodumene, Ravensthorpe. Large pale green crystals in granite.

MAGNESIUM.

This metal was first separated and described at the beginning of the 19th century, though its compounds had been in use for some time previous to this. It is a soft white metal, which does not tarnish in dry air but is coated with a film of oxide on exposure to moist air. It is easily dissolved by dilute acids. It melts at a red heat and burns readily in the air with a brilliant flame.

Magnesium does not occur native in the earth, but is a universal constituent of all rocks, forming a considerable proportion of serpentine and other basic igneous rocks. Comparatively few minerals are, however, capable of successful treatment for the production of the metal and its artificial compounds. Of these the most important is the carbonate, magnesite; the sulphates, epsomite and kieserite, and the chloride of potassium and magnesium, carnallite, are also valuable minerals. Asbestos, talc and other magnesian silicates are dealt with under the title "Silica and silicates." Magnesium chloride and sulphate are constituents of almost all well and bore waters.

Metallic magnesium in the form of ribbon or powder is burnt to produce a brilliant illumination of interiors, underground hollows, etc., for photographic or show purposes; it is also used for signalling purposes and in pyrotechny. Small quantities are used for various analytical purposes.

Of artificial compounds the most important is the oxide, magnesia, large quantities of which are made into fire brick or pressed direct into the linings of furnaces for the production of "basic" steel, and of kilns for burning hydraulic cement. It is also used as a non-conducting covering for boilers, etc., and as a starting point for the manufacture of various other magnesium compounds. The hydrous sulphate, known as Epsom salts, is

largely used in the manufacture of dyes, soaps, and paints, in tanning leather, and in medicine. The chloride is used in the textile industry and as a source of metallic magnesium, the sulphite in cleaning wood-pulp for paper manufacture.

Magnesite.—Carbonate of magnesium, $MgCO_3$. Magnesium, 25 to 28 per cent.; magnesia, 42 to 47 per cent.; carbon dioxide, 47 to 52 per cent. Occasionally crystallised, usually massive compact granular or earthy. White, yellowish, brownish; transparent to opaque. Soft or hard, brittle. G., 3·1. Occurs in veins in serpentine and other rocks, and in boulders in the weathered rocks.

Uses.—Chiefly burnt to convert it into magnesia, for the manufacture of refractory bricks and furnace linings. For this purpose it should contain a small proportion only of silica. Also used in the manufacture of magnesium chloride, sulphite, and sulphate (Epsom Salts). Large quantities used for the production of carbon dioxide for aerating waters, etc., magnesia or magnesium sulphate being obtained as bye-products. Magnesite used as a source of magnesium salts should be as free as possible from iron and lime.

334.—Magnesite, Coolgardie.

2945.—Magnesite, Kalgoorlie.

Epsomite.—Native Epsom Salts. Hydrous sulphate of magnesium, $MgSO_4.7H_2O$. Magnesia, 16 per cent. Crystallised or in fibrous masses. White or yellowish, transparent to translucent. Very soft, brittle. Soluble in water. G., 1·7. Occurs in sedimentary deposits in ancient or recent lake-beds; common in mineral waters.

Uses.—After purification marketed as Epsom salts, the uses of which are given above.

Kieserite.—Hydrous sulphate of magnesium, $MgSO_4.H_2O$. Magnesia, 29 per cent. Rarely crystallised, usually massive granular or compact. White, or grey; translucent or opaque. Soft, friable or firm. G., 2·5. Occurs in sedimentary beds.

Uses.—An important source of Epsom Salts.

Carnallite.—Hydrous chloride of magnesium and potassium. Magnesium, 8 per cent.; potassium, 14 per cent. Granular massive, rarely crystallised. White or pink, transparent to translucent. Very soft, brittle. G., 1·6. Occurs in beds in sedimentary deposits.

Uses.—Used as a source of metallic magnesium. Also a valuable fertiliser owing to the large percentage of soluble potassium in it. For the latter purpose its value depends entirely upon the percentage of potassium present; for the former purpose the purest mineral is the most valuable.

Dolomite.—*See* page 20.

MANGANESE.

The metal manganese was discovered at the latter end of the 18th century. In its pure form it only appears in commerce as a chemical curiosity. It is a very hard brittle metal, resembling cast iron in appearance and weight, but it is so susceptible to the action of the air that it can only be preserved in sealed bottles or under mineral oil.

Manganese does not occur in nature in the metallic state, but is usually found combined with oxygen as one of the several oxides, which constitute the chief source of the metal. It is also a universal constituent, in small proportion, of all rocks, especially the more basic, darker coloured, igneous rocks occurring in them in combination with silica, but not in such a form as would constitute a commercial source of the metal. Workable deposits of the ores are, however, largely found in close association with such rocks or the debris resulting from their decomposition. Ores are also frequently found in association with limestone, being originally absorbed from the seawater by a living organism and subsequently secreted in the substance of the shells or corals which have gone to build up the beds of rock.

In its pure state manganese has no application in the arts. Of its alloys those with iron are the most important, viz., ferro-manganese, containing from 25 to 75 per cent. of manganese, and spiegel-eisen, containing from 2 to 25 per cent. These alloys are largely used in the manufacture of Bessemer steel. An alloy of manganese, copper and zinc has been used as a substitute for German silver, which it resembles very closely.

Compounds of manganese are used in large quantities for various technical purposes. This is especially true of the dioxide (MnO_2) which occurs in nature in Pyrolusite (*q.v.*). Potassium and sodium permanganates ($KMnO_4$ and $NaMnO_4$) are extensively used as disinfectants and deodorants, owing to the ease with which they give up part of the oxygen contained in them.

The natural oxides of manganese are all used for both colouring and decolourising glass; for colouring pottery and brick; for calico-printing and dyeing; and in manufacturing certain paint. A considerable quantity of manganese is also used as a flux in lead smelting, oxide of manganese in conjunction with oxides of iron and lime forming a readily fusible slag with the siliceous gangue of the lead ore. For fluxing purposes the value of the ore depends upon its richness in manganese and its freedom from silica; iron oxide is not looked upon as an objectionable constituent. The oxides and carbonate are the only ores used as a source of the metal in the form of spiegel or ferro-manganese. For this purpose the ore should be rich in manganese, poor in silica, and contain only very minute amounts of sulphur or phosphorus, both of which tend to reduce the value of the final product, Bessemer steel. A third main use of the natural oxides of manganese is in the production of chlorine, bromine, and iodine. The most important of these is chlorine, which is employed in extracting gold from its ores and

refining it, and in the production of bleaching powder or chloride of lime for bleaching and disinfecting. This is the chief use to which it is put in Australia, the chlorine being produced by heating a mixture of salt and sulphuric acid with any ore of manganese containing the dioxide. For this purpose the value of the ore depends entirely upon the proportion of dioxide present, and is bought at so much "per unit," that is so much for every one per cent. of dioxide (MnO_2) in the ore.

The following are the chief compounds of manganese occurring in nature:—

Pyrolusite.—Dioxide of manganese, MnO_2. Manganese, 60-63 per cent.; manganese dioxide, 95-100 per cent. Soft, black, crystalline or massive, opaque. G., 4·8.

Uses.—This mineral is the most useful ore for the production of chlorine, and the manufacture of permanganates owing to the fact that it is richer in the dioxide than any other manganese ore. It should be noted in this connection that the "pyrolusite" of the Australian miner and ore-dealer includes practically all native manganese oxides such as Psilomelane, etc. Pyrolusite is also used as a flux, as a source of manganese alloys, and for all other purposes mentioned above.

4340.—Pyrolusite, Gladstone, Qld.

Braunite.—Oxide and silicate of manganese $4MnO.3MnO_2.SiO_2$. Manganese, 63 per cent.; silica, 10 per cent.; manganese dioxide, 43 per cent. Crystalline or massive. Black, opaque, hard, brittle. G., 4·8. A somewhat rare ore.

Uses.—Of little use for the manufacture of chlorine owing to the low percentage of the dioxide present. It can be used for all other purposes, but the invariable presence of a considerable percentage of silica makes it an inferior ore under all circumstances.

Manganite.—Hydrated oxide of manganese, $MnO.Mno_2.H_2O$. Manganese, 63 per cent.; manganese dioxide, 50 per cent. Crystallised or massive. Soft, brittle, black, opaque, sub-metallic. G., 4·3.

Uses.—Same as Braunite.

T. 189.—Manganite, Michigan, U.S.A.

Psilomelane.—Hydrated oxide of manganese, $xMnO.MnO_2.yH_2O$. Variable in composition, but averages: manganese 55 per cent., manganese dioxide, 70 per cent.

A common variety of this mineral known as *Asbolite* frequently contains sufficient cobalt and nickel to constitute an ore of those metals, *q.v.*, (massive or concretionary). Variable hardness, black, opaque. G., 3·7 - 4·7. A commonly occurring ore.

Uses.—This ore is used for all the purposes to which Pyrolusite is put, and after that mineral is the most valuable of the manganese ores.

4444.—Psilomelane, Ravensthorpe Range, near Mt. Desmond.

1801, etc.—Asbolite. (*See* Cobalt.)

Rhodocrosite.—Carbonate of manganese, $MnO.CO_2$. Manganese, 48 per cent. (crystalline or massive). Somewhat hard; pink, grey, or brown; semi-opaque. An uncommon ore. G., 4·4.

Uses.—Can be used as a flux or as a source of the metal.

T. 195.—Rhodocrosite, Colorado, U.S.A.

MERCURY.

Mercury is the only metal which at ordinary temperatures is liquid. It was known some centuries before the Christian era. It is a bright, metallic, white, mobile liquid, which does not tarnish in the air, and readily dissolves gold, silver, and many other metals. Its specific gravity is 13·5.

Mercury is found native in small globules, but its commonest native compound and chief ore is the sulphide, cinnabar. It also occurs as the telluride, coloradoite, and in some varieties of fahl-ore, but neither of these minerals are sufficiently plentiful to constitute sources of the metal. Mercury ores usually occur in veins or stockworks in slate, limestone, or igneous rocks.

By far the greater part of the world's production of mercury is employed in extracting gold and silver from their ores. Smaller quantities are used in the electrolytic production of caustic soda, for thermometers, barometers, battery zincs, etc., and the production of amalgams, or alloys of mercury with other metals. Sodium amalgam is added to ordinary mercury to make it dissolve gold more actively, and is also used as a reducing agent in preparing various organic products. Tin amalgam is used as a backing for glass to produce an ordinary mirror. Various amalgams are used in dentistry as stopping for teeth. Mercurous chloride, or calomel, is used in medicine; mercuric chloride, or corrosive sublimate, as an antiseptic and vermicide, especially for preserving timber, also in making aniline-red, in dying and calico-printing, and in etching steel plates. Mercuric sulphide or vermilion is an important pigment. Several mercury salts are employed as analytical re-agents and in medicine. Mercury fulminate is an extremely explosive salt used for detonators and percussion caps. Mercuric oxide is sometimes used in anti-fouling paint for ships' bottoms.

Mercury (Native).—Practically pure mercury. In small liquid globules, white, metallic, brilliant. G., 13·6.

Uses.—A minor source of the metal and its compounds.

Cinnabar.—Sulphide of mercury, HgS. Mercury, 86 per cent. Crystalline, granular, massive, or earthy. Red, sometimes brownish or leaden; transparent to opaque. Lustre, brilliant to dull. Soft, slightly sectile. G., 8·1.

Uses.—The main source of the metal and its compounds. Ores as low as 0·3 per cent. have been worked at a profit, though 1 to 3 per cent. is the usual smelting grade.

T. 34.—Cinnabar, California, U.S.A.

MOLYBDENUM.

This rare metal, first discovered in 1780, is very similar to silver in appearance, but is somewhat harder, lighter, and more infusible. It is not affected by the air at ordinary temperatures, and resists the action of many acids. In spite of its many useful properties, it has not yet found any application in the arts except in combination with other metals, etc.

The commonest ore of molybdenum is the sulphide, molybdenite, the metal iteelf not occurring uncombined in nature. The oxide, molybdite, sometimes occurs near the surface in sufficient quantities to constitute an ore. The usual matrices of both these minerals are veins of quartz or calcite traversing igneous rocks. Ores of copper, bismuth, etc., usually accompany them.

Crude molybdenum, containing carbon and iron, is obtained by the electric smelting of the roasted ores, and ferro-molybdenum, an alloy of iron and molybdenum, by adding iron ores to the smelting mixture. A considerable demand for these products has arisen since the discovery that the addition of a little of either of them to chrome steel renders it self-hardening. In this respect it is said to be better than tungsten.

Ammonium molybdate is used largely in analytical work for the estimation of phosphorus. Molybdenum tannate is a useful dye for leather, producing, in conjunction with logwood, various shades of yellow and brown. In pottery molybdenum blue or blue carmine is used to impart a blue colour of great brilliancy and durability. Compounds of this metal are also used for dyeing silk blue. Sodium molybdate has been used in the treatment of dropsy.

Molybdenite.—Sulphide of molybdenum, MoS_2. Molybdenum, 60 per cent. Foliated, scaly, or sometimes granular. Metallic, opaque, lead coloured, closely resembling graphite. Very soft. G., 4·7.

Uses.—This is the chief source of the crude metal and its alloys and salts. The ore to be saleable must be concentrated by hand or machinery up to at least 45 per cent. of metal, and must be entirely freed from copper compounds. The Elmore process of oil concentration has been found successful in some cases.

1316.—Molybdenite in vein quartz, Clackline.

387.—Molybdenite in amphibolite, Coolgardie.

4353.—Molybdenite in quartz, Chowey Creek, Mt. Shamrock, Queensland.

Molybdite.—Oxide of molybdenum, MoO_3. Molybdenum, 66 per cent. In fine crystals, fibrous, massive, or earthy. Yellow. Very soft. G., 4·5.

Uses.—This is much rarer than molybdenite, but, as it contains more of the metal and requires no roasting to remove sulphur, it would be somewhat more valuable but for the difficulty of concentrating it. (*See* remarks under molybdenite.)

NICKEL.

This useful metal has been known for about a century and a half, but has only within the last few years been extensively used in the arts. It is a bright, greyish-white metal; hard, ductile, and malleable. It is capable of taking a very high polish, which is not easily dulled by air or water. It is magnetic.

Nickel does not occur native, though an alloy with iron forms the chief constituent of many meteorites. Its chief ores are garnierite, a silicate of nickel and magnesium found chiefly in New Caledonia, and nickeliferous pyrrhotite, a sulphide of iron and nickel. Of minor importance are the sulphide, arsenide, and arsenate described below. A great number of other minerals are known which contain nickel, any of which, if found in sufficient quantity, would form a valuable source of the metal. They appear, however, to be very rare, and are not therefore described here. Descriptions will be found in any text book of Mineralogy. Nickel occurs to a slight extent in all cobalt ores, and cobalt in all nickel ores. The ores occur usually in association with basic igneous rocks.

The most important use of nickel is in making various alloys, but the pure metal is largely used for various metal instruments, ornaments, and other articles, as well as for plating such articles when made of cheaper metals. By far the most important alloys of nickel are those with steel, which is thereby rendered much stronger, harder, more elastic and less liable to corrosion. Such steels are extensively used for armour plate, projectiles, heavy guns, propeller-shafts, railway axles, etc. The nickel is added to the steel either in the form of the pure metal, or one of the alloys ferro-nickel, chrome-nickel, tungsten-nickel, or molybdenum-nickel, whose names indicate their composition. Alloys of nickel and copper in various proportions are used in many countries for coinage. An alloy of nickel, copper, and zinc, known as "German Silver" is extensively used for various implements and ornaments.

Nickel oxide is used to add to steel for making nickel-steel. Nickel ammonium sulphate in solution for nickel-plating.

Garnierite.—Hydrous silicate of nickel and magnesium. Nickel, 43 to 48 per cent; cobalt, trace to ·5 per cent. Massive, clay-like. Dark or pale green, or chocolate; opaque, dull. Very soft. G., 2·5. Occurs in veins and stockworks in serpentine and peridotite.

Uses.—One of the chief sources of the metal and its compounds. Ores practically free from cobalt are the most valuable. For market the ore should be hand picked up to a minimum of 7 per cent.

4350.—Green Garnierite, New Caledonia.

Nickeliferous Pyrrhotite.—Sulphide of iron and nickel. $(FeNi)_7.S_8$. Nickel, 0·5 to 10 per cent; cobalt, trace to 0·5 per cent. Metallic, massive, or crystallised. Bronze-brown, opaque, magnetic. Soft, brittle. G., 4·6. Occurs in veins with quartz, etc. in basic igneous rocks.

Uses.—An important source of nickel and its compounds. The freer the ore from cobalt the more valuable it is. For smelting, the ore should be dressed to a minimum of 2 per cent. nickel.

1415.—Nickeliferous Pyrrhotite, Southern Cross.

T. 122.—Nickeliferous Pyrrhotite, Sudbury, Canada.

Millerite.—Sulphide of nickel, NiS. Nickel, 64 per cent. In fine crystals or radiated massive. Metallic, yellow or brown, opaque. Soft, brittle. G., 5·5. Found in veins of quartz or calcite.

Uses.—A minor source of nickel owing to its rarity.

T. 124.—**Millerite, Pennsylvania, U.S.A.**

Niccolite (Kupfernickel).—Arsenide of nickel, NiAs. Nickel, 33 to 44 per cent. Massive, metallic. Light copper colour, opaque, tarnishes readily. Hard, brittle. G., 7·5. Found in veins of quartz or calcite.

Uses.—*See* Millerite.

T. 119.—Niccolite, Bebra, Saxony.

PLATINUM, IRIDIUM, AND OSMIUM.

These are all rare metals resembling one another closely and found closely associated in nature, they will therefore be dealt with together.

Platinum is a bright, greyish, white, malleable, and ductile metal. It is very infusible and not readily acted on by the strongest acids. At a red heat platinum can be welded with ease. Its specific gravity is 21·5. Its chief use is in the manufacture of chemical ware such as vessels for the concentration of acids, weights, etc. Other important uses are in the manufacture of platinotype photographic paper, and in various electrical appliances. Besides this it is used in jewellery, in physiological and surgical instruments and in dentistry, and in the "Contact Process" of manufacturing sulphuric acid. Alloyed with iridium it is not only used for chemical ware, but also for standard weights and measures, etc. Platinum tetrachloride is used as a chemical re-agent.

Iridium is a hard, white, brittle metal, extremely heavy, its specific gravity being 22·4. It is not used uncombined in the arts, but from 5 to 10 per cent. is frequently alloyed with platinum, which is rendered much harder and more durable thereby. Iridium oxide is used in porcelain painting. An alloy with osmium is used for compass bearings and for tipping pens.

Osmium is an extremely hard, bluish metal, insoluble in all acids, even *aqua regia*. It is one of the heaviest substances known, having a specific gravity of 22·5. Its chief use is in incandescent electric lights, for which it is the most efficient material yet experimented with. It is also used in alloys with iridium, as described above. Osmium oxide is used as a black stain in optical apparatus.

These three metals are almost always found in nature together, rarely in lodes, more frequently in river or beach sands in the form of native platinum, native iridium, and osmiridium. The only native compound of these metals of any importance is the arsenide of platinum, sperrylite.

Platinum (Native).—Platinum alloyed with iron, iridium, etc. Platinum, 50 to 86 per cent.; iridium, trace to 20 per cent.; osmium, trace to 10 per cent. In small grains or scales, occasionally in large nuggets. Greyish white, bright, metallic, malleable, soft, sometimes magnetic. G., 14 to 19.

Uses.—The chief source of platinum and its compounds, and to a minor degree, of iridium and osmium.

5192.—Platinum Sands, Clarence River. N.S.W.

Iridium (Native).—Iridium alloyed with platinum, etc. Iridium, 30 to 76 per cent.; platinum, 20 to 55 per cent.; osmium, trace. In angular white metallic grains. Slightly malleable, hard. G., 22·7.

Uses.—A rare mineral, used as a source of iridium and platinum and their compounds.

Osmiridium (Iridosmine).—Native alloy of iridium and osmium. Iridium, 43 to 77 per cent.; osmium, 17 to 49 per cent.; platinum, trace to 3 per cent. In small flattened grains, sometimes hexagonal in outline, with basal cleavage. White or grey, metallic. Barely malleable, hard. G., 20. Found in sands associated with platinum, gold, etc.

Uses.—The chief source of iridium and osmium and their compounds.

5193.—Osmiridium, Clarence River, N.S.W.

Sperrylite.—Arsenide of platinum, $PtAs_2$. Platinum, 56 per cent. In small cubical crystals. White, metallic, brilliant, opaque. Brittle, hard. G., 10·6.

Occurs in veins, usually with copper ores, but occasionally with nickel and gold.

Uses.—A minor source of platinum and its compounds.

POTASSIUM.

This metal was first separated early in the 19th century, though some of its compounds, notably nitre, had been in use by man from time immemorial. It is a very soft, white, plastic, and sectile metal, which is rapidly oxidised by air or water; so that it has to be preserved under mineral oils. It is one of the lightest metals known, its specific gravity being less than one.

Potassium occurs as a constituent of very many rocks, especially granites, but cannot be profitably extracted from them or from any of the natural silicates, such as potash mica or felspar. The commercially most important minerals containing potassium are the

nitrate, nitre, or saltpetre; the chloride, sylvite; the double chloride with magnesium, carnallite; and the double sulphate and chloride, kainite.

Metallic potassium is not of commercial importance. Of the highest importance, however, are the nitrate and chlorate, used as constituents of various explosives, and the various soluble potash salts used as fertilisers. Potassium cyanide is largely used as a solvent for gold. Potassium chromate and bichromate are put to many uses (*see* p 26). Potash alum is a most useful salt, and is described under aluminium, page 12. Potassium hydrate, carbonate, ferrocyanide, iodide, bromide, etc., are put to various medicinal and other uses.

Nitre.—Nitrate of potassium, KNO_3. Potash, 46 per cent.; nitrogen pentoxide, 53 per cent. Crystallised, in thin crusts or powder. White, translucent. Very soft, brittle. G., 2·1. Occurs as an efflorescence on the soil in dry countries.

Uses.—After refining, is largely used in manufacturing gunpowder and other explosives. Also used as a fertiliser and in curing meat, etc.

Sylvite.—Chloride of potassium, KCl. Potassium, 52 per cent. (equal to potash 62 per cent.), but frequently intimately mixed with common salt. Crystallised, massive, granular, or compact. Colourless, white, or tinted. Transparent to translucent. Very soft, brittle. G., 2·0. Occurs in beds in sedimentary deposits.

Uses.—Used as a fertiliser and as a source of various salts of potassium, its value depending upon its purity and richness in potassium.

Carnallite.—*See* page 39.

Kainite (Kainit).—Hydrous chloride and sulphate of potassium and magnesium. Potassium 13 to 16 per cent. (equal to potash 16 to 20 per cent). Crystallised or granular, massive. Colourless, white, or tinted; translucent. Soft, brittle. G., 2·1. Occurs in sedimentary deposits.

Uses.—A very valuable fertiliser and source of potassium salts. Value depends on purity and richness in potassium.

SILVER.

Silver has been known to man for many centuries, being one of the few metals known to the ancients. It is white, and capable of a most brilliant polish, which undergoes no change in air or water unless sulphur be present, when it is blackened. In malleability and ductility it is second only to gold, than which it is slightly harder. It is the best known conductor of heat and electricity. Its specific gravity is 10·5, or between that of copper and lead.

Silver occurs native in a state of considerable purity and also occurs alloyed with gold. It also occurs in a vast number of compounds, comparatively few of which, however, constitute important

ores of the metal. Chief of these are the sulphide, argentite; the sulphides of silver, antimony, and arsenic, stephanite, pyrargyrite, proustite, and polybasite; the chloride, cerargyrite, and the chloro-bromide, embolite. Most lead ores, especially galena, contain more or less silver, also most copper ores, especially tetrahedrite (fahl-ore) and chalcocite. Blende, pyrites, and mispickel, also, at times, carry notable quantities of silver.

Metallic silver is largely used in the arts for preparing alloys and silver salts, and for plating various articles of utility and ornament. It is also used in assaying. The chief alloy is that with copper, which possesses all the beauty of the original silver, but is much harder. It is extensively used for coinage, tableware, jewellery, and innumerable articles of ornament, etc. The chief use for silver salts is in photography; the nitrate, bromide, chloride, and other compounds being used for this purpose. The nitrate is also used in analytical work, in medicine, and in the manufacture of marking inks.

Native ores of silver are used solely for the production of the metal, from which alloys or salts are subsequently obtained as desired. Their value depends upon the amount of the metal present and the ease with which it can be extracted. They occur in lodes and veins in crystalline and other rocks.

Silver (Native).—Silver, 70 to 99 per cent.; gold, trace to 30 per cent. Crystallised, dendritic, massive, or in scales. White, or tarnished grey or black, metallic, opaque. Malleable, soft. G., 10·5.

Uses.—*See* above. The gold present is occasionally of considerable value.

T. 24.—Native Silver, Spain.

Argentite.—Sulphide of silver, Ag_2S. Silver, 87 per cent. Crystallised or massive. Black, metallic, opaque. Very soft, sectile. G., 7·3.

Uses.—*See* above.

Stephanite.—Sulphide of silver and antimony. Silver, 68 per cent. Crystallised or massive. Black, metallic, opaque. Very soft, brittle. G., 6·2.

Uses.—*See* above.

Pyrargyrite (Dark Ruby Silver Ore).—Sulphide of silver and antimony. Silver, 58 to 61 per cent. Crystallised or compact, massive. Black or deep red, metallic, opaque except in thin splinters. Soft, brittle. G., 5·8.

Uses.—*See* above.

Proustite (Light Ruby Silver Ore).—Sulphide of silver and arsenic. Silver, 63 to 65 per cent. Crystallised or compact, massive. Red, brilliant, transparent to translucent. Very soft, brittle. G., 5·6.

Uses.—*See* above.

Polybasite.—Sulphide of silver, antimony, and copper. Silver, 62 to 72 per cent. Crystallised, metallic. Black and opaque, except in thin splinters, which are red to translucent. Soft, brittle. G., 6·1.

Uses.—*See* above.

Cerargyrite (Horn Silver).—Chloride of silver, AgCl. Silver, 75 per cent. Sometimes crystallised, usually massive, waxlike. White, greyish, or greenish, turns brown on exposure to the light. Transparent or translucent. Very soft and sectile. G., 5·5.

Uses.—*See* above.

T. 27.—Cerargyrite, Broken Hill, N.S.W.

Embolite.—Chloro-bromide of silver, Ag(ClBr). Silver, 61 to 72 per cent. Crystallised or massive. Green or yellow, darkening on exposure to light. Transparent to translucent. Very soft, sectile. G., 5·4.

Uses.—*See* above.

Argentiferous Galena, Tetrahedrite, and Blende, are important ores of silver, but when argentiferous have their usual appearance and characteristics. They are described elsewhere. (Galena, page 36, tetrahedrite, page 30, blende, page 61.) Many other minerals contain considerable percentage of silver, and if found in any quantity would constitute valuable sources of the metal. These minerals are of rare occurrence, and are described in text books of Mineralogy, *q.v.*

SODIUM.

Sodium, the metallic constituent of common salt, was first isolated and examined early in the 19th century. It is a soft, white, plastic metal, which is slightly lighter than water. It melts at a temperature below that of boiling water, and is one of the best known conductors of heat and electricity. It oxidises rapidly in moist air or in contact with water.

Sodium does not occur native, but is widely distributed in the form of various rock-forming silicates and as the chloride, common salt. This latter is the chief source of the metal and its salts. The nitrate, chili-nitre; sulphate, thenardite; and sesquicarbonate, trona, also occur native.

Metallic sodium is a most useful reducing agent, and is therefore used in the reduction of aluminium and other metals from their ores, as well as in the preparation of many organic compounds. Sodium amalgam, formed by dissolving sodium in mercury, is a good solvent for gold, and is largely used in gold amalgamation. A liquid alloy of sodium and potassium is used for high temperature thermometers.

The artificial compounds of sodium are manufactured on an enormous scale for many purposes. The peroxide is a most useful bleaching and general oxidising agent. Sodium chloride, both

crude and refined, is perhaps the most useful of all sodium compounds (*see* under Salt, *infra*). The carbonate, "soda," is mainly used in the manufacture of soap and glass, besides being put to a great number of other industrial and domestic purposes, such as the extraction of aluminium from its ores, the production of caustic soda, the refining of gold, and other metals, etc., in photography, analytical chemistry, etc. The bicarbonate is used as a source of carbonic acid for aerated waters, in cookery, in metallurgical processes, in scouring wool, etc. The hydrate, caustic soda, is used for the same purposes as the carbonate, as well as for the production of soluble glass, various organic dyes, and bleaching liquors, and for purifying crude oils, etc. The sulphate is used in the manufacture of many forms of glass; the thiosulphate in extracting silver from its ores, and in photography. Many other sodium salts are used for various industrial, medicinal, and other purposes.

Salt.—Chloride of sodium, NaCl. Sodium, 61 per cent.; chlorine, 39 per cent. Usually crystallised, also massive, compact, or granular. Colourless or tinted; transparent to translucent. Soft, brittle, G., 2·2. Occurs in stratified deposits or in beds of salt lakes. Also in solution, in large quantity, in sea water, and the water of many lakes and springs.

Uses.—Chiefly used, both crude and refined, as a food for men and animals, and as a source of soda and other sodium compounds. Also largely used as a source of chlorine and hydrochloric acid, as a preservative of meat, skins, etc.; as a glazing material for pottery-ware; in the metallurgy of gold and silver, etc. The value of the mineral depends upon its purity and freedom from admixed sand and compounds of lime, magnesium, and iron.

5365.—Crystallised Salt, Rottnest Island.

Chili Nitre.—Nitrate of sodium, $NaNO_3$. Soda, 36 per cent.; nitrogen pentoxide, 64 per cent. Sometimes crystallised, usually massive. White or tinted, transparent. Very soft, somewhat sectile. G., 2·3. Occurs in beds of dry lakes in desert regions.

Uses.—Chiefly used as a fertiliser and as a source of nitric acid, the percentage of nitrogen pentoxide governing its value for both purposes. Also used in the manufacture of nitre and sodium nitrate (for dyeing).

Trona.—Hydrous sesquicarbonate of sodium. Soda, 41 per cent.; carbon dioxide, 39 per cent. Crystallised or massive, fibrous or columnar. Grey or yellowish white, translucent. Soft, brittle. G., 2·1. Occurs in beds or crusts in the beds of dry lakes in desert countries.

Uses.—A source of sodium carbonate.

Borax.—Borate of sodium; *see* page 17.

STRONTIUM.

Strontium is a somewhat rare metal, which has been known for about a century. It is a soft, yellowish-white metal, of the same weight as aluminium. It is malleable, melts readily, oxidises rapidly in the air, and decomposes water with violence.

Strontium occurs in small quantities in most limestones and other mineral substances containing calcium. Its only ores are the carbonate (strontianite), and the sulphate (celestite).

The metal finds no application in the arts. The hydrate is used in the extraction of sugar from molasses, and the nitrate in pyrotechny as a constituent of all red fires.

Strontianite.—Carbonate of strontium, $SrCO_3$. Strontia (strontium oxide), 63 to 70 per cent. Crystallised, fibrous, or granular. Pale green, white, yellow; transparent to translucent. Soft, brittle. G., 3·7. Occurs in veins in granite or limestone.

Uses.—A source of strontium salts.

Celestite.—Sulphate of strontium, $SrSO_4$. Strontia, 50 to 56 per cent. Crystallised, fibrous, globular, or granular. White, pale blue, pale red; transparent to opaque. Soft, brittle. G., 4·0. Occurs in veins, etc., in limestone and sandstone.

Use.—A source of strontium salts.

SULPHUR.

Sulphur is one of the commonest of the non-metallic elements, and has been known from time immemorial. In its ordinary form it is a bright yellow crystalline substance, which melts readily and burns with the production of pungent fumes.

Sulphur occurs to a considerable extent in the free state in all volcanic districts. Its commonest compound is pyrites, sulphide of iron; whilst sulphides of lead, copper, and other metals are of frequent occurrence. Sulphates of lime and other metals are also common, but do not constitute a source of sulphur. Sulphur is also a constituent of coal and of animal and vegetable substances.

The most important use of sulphur is in the manufacture of sulphuric acid, but it is also largely used for making gun and blasting powder, sulphurous acid for vulcanising rubber, as an insecticide, for fumigating, and for the preparation of various sulphur compounds. By far the most important compound of sulphur is sulphuric acid, used in the manufacture of sodium carbonate (soda), hydrochloric, nitric, stearic, and other acids, alum, ether, nitro-glycerine, superphosphate, various metallic sulphates, etc. Sulphurous acid, metallic sulphites, and sulphates are used for a variety of purposes.

Sulphur (Native).—Pure sulphur mixed with various quantities of clay and other accidental impurities. Crystallised, massive, or earthy. Yellow, transparent to translucent. Very

soft, brittle. G., 2·0. Occurs in beds, veins, and irregular deposits in the vicinity of active or extinct volcanoes and hot springs.

Uses.—An important source of refined sulphur and sulphuric acid. Value depends upon its purity.

Pyrites.—Sulphide of iron, FeS_2. Sulphur, 53 per cent. Metallic, massive, or crystalline. Pale brass-yellow, opaque. Hard, brittle. G., 5·0.

Uses.—Largely used as a source of sulphur in sulphuric acid manufacture. For this purpose the ore should be free from arsenic, and should be dressed up to at least 45 per cent. Also used to a slight extent as a source of copperas (iron sulphate).

4294.—Pyrites, Crystals, Broad Arrow.
4039.—Pyrites, Northampton.
1103.—Pyrites, Coolgardie.

THALLIUM.

This very rare metal was discovered in 1861. It is bluish white in colour, soft and malleable, and melts below a red heat. It is slowly affected by air and water at ordinary temperatures. Its specific gravity is slightly higher than that of lead.

Thallium does not occur native, but is found in traces in certain samples of pyrites, and can be recovered from the flue dust when such samples are burnt for sulphuric acid manufacture. Thallium also occurs as the sulpharsenide, lorandite; and the selenide of copper, silver and thallium, crookesite.

Metallic thallium is not of any use in the arts, but the oxide is a constituent of certain varieties of optical glass, and the nitrate is used in examining gems, natural and artificial, and for certain other laboratory purposes.

Lorandite.—Sulpharsenide of thallium, $TlAsS_2$. Thallium, 59 per cent. Crystallised with a perfect cleavage. Red, often tarnished dark grey, metallic, brilliant, translucent. Soft, flexible. G., 5·5.

Uses.—A source of thallium salts.

Crookesite.—Selenide of copper, silver and thallium. Thallium, 16 to 19 per cent.; silver, two to five per cent. Massive, compact. Lead grey, metallic, opaque. Soft, brittle. G., 6·9.

Uses.—A source of thallium salts and silver.

THORIUM.

This rare metal was discovered in 1828. It is grey in colour, as heavy as lead, and not altered by the atmosphere, unless strongly heated, when it takes fire and burns.

Thorium occurs in nature in several rare silicates, titanates, and phosphates, of which the most important is monazite, which is

at present almost the sole source of thorium compounds. These minerals occur in crystalline rocks, especially granite and gneiss, and the heavy sands in rivers and on ocean beaches, resulting from their weathering. It is from these sands that almost all the commercial ore is obtained.

Metallic thorium has not, so far, been put to any use. Its most important compounds are the oxide and nitrate. The former, when mixed with a little oxide of cerium or zirconium, possesses in a marked degree the power of giving out an intense light when heated. For this reason it forms the chief constituent of Welsbach gas mantles and of the glower of the Nernst electric light. The nitrate is the salt which is used as a source of the oxide for these lamps.

Monazite.—Phosphate of cerium, lanthanum, and didymium $(CeLaDi)PO_4$, with variable amounts of thorium oxide from a trace up to 18 per cent., the average being $2\frac{1}{2}$ to $3\frac{1}{2}$ per cent. Crystalline or in water-worn grains, yellow or brown, semi-transparent, brittle, hard. G., 5·1.

Uses.—This mineral is the chief source of thorium salts, and its value is entirely dependent upon the percentage of that metal present. The sands containing the mineral are concentrated by hand or in hydraulic sluices, and if the resulting material does not contain 60 or 70 per cent. of monazite, it is still further concentrated by drying and removing all magnetite and titaniferous iron by an electro-magnet. For the market the dressed ore should contain 70 to 95 per cent. of the pure mineral.

5437.—Monazite Sand, North Carolina, U.S.A.

Thorite.—Silicate of thorium, $ThO_2.SiO_2$. Thorium oxide, 50 to 81 per cent. Crystallised or massive; yellow, brown, or black; semi-transparent, brittle, hard. G., 5.

Uses.—A source of thorium compounds, the value of the mineral depending on its thorium contents.

TIN.

Tin has been known for a great number of centuries, the Romans drawing supplies from Cornwall. It is a bright white metal which does not tarnish in the air. It is ductile, and very malleable. Its specific gravity is 7·2, or the same as zinc. It melts below a red heat.

Occasional grains of metallic tin have been found in various parts of the world, but they are very rare, and their origin is a matter of doubt. The chief ore of tin is the dioxide, cassiterite, or tinstone. Small amounts of the metal have also been obtained from stannite, a sulphide of tin, copper, and iron.

The chief use for metallic tin is as a coating to sheet iron, the so-called tin-plate, by which the surface of the iron is prevented from rusting or from contaminating articles of food, etc., stored or cooked in them. Pure tin, or block tin, as it is called, is used also

for various domestic and other appliances, such as still-worms, etc. Thin sheet tin, or tin-foil, is used in backing mirrors, wrapping up tobacco, soaps, sweetmeats, etc. Large quantities of tin are used in making various alloys, the most important of which are the following:—Solder and pewter (tin and lead); britannia metal (tin, lead, copper, and bismuth); gun metal (bell metal and some bronze, tin, and copper); other bronzes (tin, copper, and zinc or lead); phosphor-bronze (tin, copper, and phosphorus); fusible metal (lead, tin, bismuth, etc.).

Several compounds of tin are largely used in dyeing and calico-printing; viz., stannous chloride, stannic chloride, stannic-ammonium chloride, and sodium stannate. The artificial dioxide (putty powder) is largely used for polishing metals, glass, stones, and gems, and as a constituent of enamels. Stannic sulphide, or mosaic gold, was at one time used as a substitute for gold-leaf.

Cassiterite (Tinstone).—Oxide of tin, SnO_2. Tin, 68 to 78 per cent. Crystallised, massive, or in rolled grains. Brown, black, red, or grey; translucent to opaque. Hard, brittle. G., 7·0.

Occurs in veins or altered bands in granite, or in veins in sedimentary rocks close to their contact with granite; also largely in alluvial deposits derived from their denudation.

Uses.—The main source of tin and its compounds. The value of tin ores depend upon their richness in tin, and upon the nature and amount of associated minerals. For smelting, tin ores should be dressed up to at least 55 per cent. metal, as, otherwise, a large loss is experienced in smelting. Where the tinstone is accompanied by wolfram, tantalite, stibiotantalite, or other minerals of the same or higher specific gravity, the ordinary methods of water concentration are unable to remove these impurities, and the concentrated ore is consequently low in grade and loses greatly in value. Such constituents are, therefore, a considerable drawback to the ore. Stibiotantalite is also very objectionable, because it introduces antimony into the smelted tin. The most valuable tin ores are those entirely free from all other metallic minerals.

2026.—Cassiterite (stream tin), Coglegong Creek, Pilbarra Goldfield

1287.—Cassiterite (stream tin), Greenbushes. Low-grade ore with much tantalite and stibiotantalite.

1999.—Cassiterite in greisen, Greenbushes.

5397.—Cassiterite in albite vein, Moolyella, Pilbarra Goldfield.

Stannite (Tin Pyrites).—Sulphide of tin, copper, iron, and zinc. Tin, 23 to 27 per cent.; copper, 29 per cent. Massive or granular. Metallic, black or dark grey, opaque. Soft, brittle. G., 4·4. Occurs in veins in granite or slate.

Uses.—A very rare source of tin and its compounds. The copper present adds to the value of the mineral.

T. 19.—Stannite, Cornwall, England.

TITANIUM.

This metal in small quantities is very widely distributed, being found in all igneous rocks and many sedimentary ones. It was first discovered at the end of the eighteenth century, and in its purest form is a dark grey powder, lighter than iron, which burns brightly on being heated in the air. It dissolves readily in dilute acids.

Titanium never occurs native. Its most common compound is ilmenite, the titanate of iron, which occurs as a constituent of many rocks, and is often found as "black sand" along rivers and sea coasts. The only other mineral which constitutes a source of titanium is the oxide, rutile.

Metallic titanium is not used in the arts, but alloys with iron, known as ferrotitanium, are at times added to cast iron and steel, with the effect of increasing their strength and hardness. Titanium oxide is used in porcelain painting, and enters into the composition of artificial teeth.

Ilmenite.—*See* page 35.

Rutile.—Oxide of titanium, TiO_2. Titanium oxide, 90 to 100 per cent.; titanium, 54 to 60 per cent. Crystallised or compact, massive. Brown, red, yellow, occasionally other tints; transparent to opaque. Hard, brittle. G., 4·2.

Uses.—A source of titanium alloys and compounds. When very pure, used for same purposes as artificial titanium oxide.

T. 111.—Rutile, Norway.
1919.—Rutile, Greenbushes.

TUNGSTEN.

This metal was discovered in 1782. It is as heavy as gold, but of grey colour, and is practically unaffected by the atmosphere. In its pure form the metal has no application in the arts.

Metallic tungsten does not occur in nature, its chief ores being the tungstate of iron, manganese, and lime, compounds of oxide of tungsten with oxides of those metals. These ores usually occur in quartz veins in granite, greenstone, or slate, and are principally mined in the United States, Austria-Hungary, Spain, and Queensland. They are known to occur in this State at Kalgoorlie, Coolgardie, Southern Cross, the ranges near Geraldton, and in the Pilbara district.

The chief use of tungsten is in hardening steel, for which purpose it is put on the market either as the impure metal or as ferrotungsten, an alloy of iron and tungsten obtained by smelting wolfram. Tungsten-steel, containing from 2 to 12 per cent. of the metal, is largely employed for guns and machine-tools, and to a less extent for rails. Nearly all the Sheffield crucible-steel makers are said to make use of it to a slight extent. The German Government has also tried it in bullet-making, as a small percentage of tungsten, added to lead, renders it harder and increases its penetrating power, without raising its melting point.

The only compound of tungsten which is used in the arts is sodium tungstate, a white crystalline salt used as a mordant and for saturating inflammable materials to render them non-inflammable, also for hardening plaster of Paris.

Wolfram or Wolframite.—Tungstate or iron and maganese, $(FeMn)WO_4$. Tungsten, 60 per cent.; tungstic oxide, 76 per cent.; massive or crystallised. Somewhat hard, black or dark brown, opaque, brilliant lustre, well marked cleavage. G., 7·4.

Uses.—Used solely as a source of tungsten, ferro-tungsten, and sodium tungstate. Its commercial value depends almost entirely upon the percentage of tungstic oxide present, but, other things being equal, an ore containing traces only of phosphorus and sulphur is worth more than one containing appreciable quantities of those substances. Ores containing wolfram are readily concentrated by hand or by machinery, and for export such concentrates should assay not less than 50 per cent. of tungstic oxide. Ore over 55 per cent. is worth considerably more per unit than ore under that grade. Any admixture of tin ore lowers the value of the product.

614.—Wolfram, Roebourne.

4356.—Wolfram, Herberton, Qld.

Huebnerite.—Tungstate of manganese, $MnWO_4$. Tungsten, 60 per cent.; tungstic oxide, 76 per cent. Similar in appearance and properties to wolfram.

Uses.—*See* Wolfram.

Scheelite.—Tungstate of lime, $CaWO_4$. Tungsten, 64 per cent.; tungstic oxide, 80 per cent.; massive or crystallised. White or slightly tinted yellow, etc., brilliant lustre. Hard, brittle. G., 6·0.

Uses, etc.—*See* remarks under Wolfram.

1299.—Scheelite, Coolgardie. Massive yellow, with a considerable amount of impurity.

1414.—Scheelite, Southern Cross. Clean, yellow, massive, in quartz vein.

1358.—Scheelite, Hillgrove, N.S.W. Clean, white, massive.

[The following extract from a report by Mr. C. F. V. Jackson, Assistant Geologist, gives some further particulars in connection with the uses and values of wolfram ores:—

Tungsten ores are frequently found associated with tin and in stanniferous leads, and considerable supplies have been derived from tin workings and by working over the waste from old tin-dressing floors. In addition to such deposits as are included above, wolfram occurs in veins and small bunches in crystalline and metamorphic rocks generally associated with a gangue of quartz. In North Queensland, the principal source of the mineral in Australia, the majority of the wolfram-producing claims lie along a fairly continuous reef of quartz, the granite for some distance on either side being intersected by an irregular system of smaller quartz veins and offshoots, from which the wolfram is chiefly obtained. The output of the Queensland fields from 1894 to the end of 1903 was estimated at 947¼ tons. New South Wales, South Australia, Tasmania, and New Zealand have pro-

duced small quantities, but the output has generally been only indirectly recorded or stated under the head of sundry minerals, and for this reason also the world's statistics are not immediately available. The tungsten combined in wolfram is generally estimated as tungstic acid, the pure mineral (tungstate of iron and manganese) containing from 73 to 76 per cent. of tungstic acid. The commercial ore, owing to the admixture of quartz and other impurities, rarely contains over 70 per cent., but should be dressed to contain not less than 60 per cent., the price for the ore being based on the ruling rate for 60 per cent., plus an additional sum for every unit of tungstic acid above 60.

Until recent years, about the only uses of tungsten were in the preparation of the salts of the metal for various technical purposes; its chief use now is either in the form of the alloy, ferro-tungsten, or as the powdered metal, in the manufacture of tungsten steel. Alloys are also made of tungsten with aluminium and copper, the latter being used in the manufacture of propeller blades. Ferro-tungsten, the alloy of tungsten, is easily prepared from wolfram and scheelite by direct reduction with iron or ferric oxide. Tungsten, when added to steel in small proportions, renders it particularly hard, and also self-tempering. Tungsten steel is therefore used in the manufacture of tool steel and wearing parts of machinery, but particularly for heavy guns and battleships' armour, Germany, in consequence, being one of the best markets for tungsten. Some three years ago it was estimated that about 75 tons of tungsten were used annually at the Krupp works in the manufacture of guns, etc., the market value of tungsten being comparatively low. During the last three years there has been a great rise in the price, and wolfram has gone from £30 per ton to £130 or £140 per ton for ore containing 60 per cent. of tungstic acid. A note in *L' Echo des Mines et de la Metallurgie* states that "the price of ferro-tungsten in France last October was, for alloy containing 80 per cent. of tungsten, 4fr. (3s. 2d.) per unit. In December it had advanced to 5fr. (4s. 9d.), and is now 7fr. (5s. 6½d.) per unit, with no chance of getting prompt delivery." This advance in price is attributed to deposits of tungsten minerals being scarce, of limited extent, and little developed; while the demand has developed so suddenly during the present year that there is no prospect of meeting it immediately. At the middle of last year wolfram was selling on the fields in North Queensland at £29 per ton, and at the end of 1903 it was £50, since when it had risen to over £120. It is there chiefly purchased by agents, who visit the field for the purpose. In this connection, however, while the general statement that wolfram in August last was worth £130 to £140 per ton might be accepted as indicating the market conditions existing, the fact is not to be lost sight of that the demand for wolfram is, comparatively speaking, small and somewhat irregular, tungsten only being used in small proportion for steel suited to a few purposes. Moreover, there is hardly reasonable ground or reliable data for assuming that the market is sufficiently stable to render mining for wolfram, except where it may be obtained as a bye-product, more than a highly speculative business, since the prices are liable to rise and fall considerably, and whilst the mineral might go up to £200, there is no sufficient guarantee that more abundant supplies and an increase of production will not suddenly put it back to £30.]

URANIUM AND RADIUM.

These two rare metals occur together in nature in the same minerals, and will therefore conveniently be dealt with together.

Uranium compounds were known and recognised as early as 1789, but it was not till 1842 that the metal was isolated. It resembles nickel in appearance, is malleable, and hard and as heavy as gold. It tarnishes readily in the air, and in the form of powder

takes fire at a temperature below the melting point of tin. Both the metal and its compounds are radio-active, that is, give out energy spontaneously and continuously.

Radium, the newest and most wonderful of all the metallic elements, is only known in combination with other elements, the metal itself not having yet been separated. The most interesting and valuable property of radium salts, and probably also of the metal, is their extreme radio-activity, which is something like a million times as great as that of uranium.

The chief ores of uranium are uraninite (pitch-blende), a complicated compound containing uranium, lead, thorium, etc.; torbernite, phosphate of uranium and copper; autunite, phosphate of uranium and lime; and carnotite, vanadate of uranium and potassium. All these appear to carry minute amounts of radium, varying from one-tenmillioneth to one-millioneth part of the whole. These ores occur principally in quartz veins and as impregnations in sandstone, sometimes also in pegmatite veins.

Metallic uranium is only of scientific interest; a little of it added to steel in the form of uranium carbide is said, however, to improve it for many purposes. The acetate and nitrate are used for analytical work and in photography. Uranium compounds are also used in enamel painting and for staining glass, uranous oxide giving a fine velvety black colour and uranic oxide a delicate greenish-yellow highly fluorescent glass, which, besides being ornamental, possesses also the property of arresting chemically active rays.

The most important radium salts are the chloride and bromide, which are being largely experimented with for various purposes.

Uraninite (Pitch-blende).—Uranate of uranium, lead thorium, etc. Uranium, 50 to 75 per cent.; radium, trace. Usually massive botryoidal, sometimes crystallised or granular. Grey, green, brown, or black, with lustre varying from submetallic to greasy or dull. Opaque, brittle, hard. G., 7 to 9·5.

Uses.—Used solely as a source of uranium and radium, its value depending on the proportion of these metals present. The relative proportion of radium present may be roughly gauged by the radio-activity of the mineral. That from Johanngeorgenstadt, in Saxony, and Joachimsthal, in Bohemia, gives the highest results.

T. 126.—Uraninite, Cornwall, England.

Torbernite (Copper Uranite).—Hydrous phosphate of uranium and copper. Uranium, 45 to 50 per cent.; radium, trace. Scaly massive or in micaceous crystals. Green, transparent or translucent. Brittle, very soft. G., 3·5.

Uses.—Constitutes a source of uranium and its salts. Radium has been detected in some specimens, though in much smaller amount than in uraninite.

T. 127.—Crystallised Torbernite, Cornwall, England.

Autunite (Lime Uranite).—Hydrous phosphate of uranium and calcium. Uranium, 44 to 50 per cent.; radium, trace. Scaly massive or in micaceous crystals. Yellow, transparent or translucent. Brittle, very soft. G., 3·1.

Uses.—*See* Torbernite.

T. 129.—Crystallised Autunite, Cornwall, England.

Carnotite.—*See* under Vanadium, *infra*.

VANADIUM.

Until quite recently vanadium, which was discovered in 1801, was thought to be a very rare metal, and, like all such, commanded a price altogether out of proportion to its usefulness in the arts. It is now known to be widely distributed over the globe in minute quantities.

Vanadium is a very infusible metal which is but little affected by the air at ordinary temperatures, or by contact with many mineral acids. It is grey in colour, and has a specific gravity about one-half that of silver.

Vanadium occurs commonly in small proportions in most iron ores (especially titaniferous magnetites) and volcanic rocks, as well as in many coals, clays, sandstones, and limestones. The clay beds in the vicinity of Sydney are vanadium-bearing, the metal showing its presence by a yellowish-green colouration on the weathered surfaces of bricks made from it. In spite of this wide distribution of the metal in traces, ores of it (*i.e.*, deposits of minerals carrying a notable percentage of the metal) are very rare. The most important of these are carnotite, a vanadate of uranium and potash occurring in Colorado; roscoelite, a silicate of potash aluminium and vanadium, which has been detected at Kalgoorlie; and vanadinite, a vanadate and chloride of lead, small crystals of which have been found in several gold reefs in Western Australia. One of the chief sources of vanadium at present is the iron slags from the Creusot Works in France, where vanadium-bearing iron ores are smelted.

The pure metal is not used for any but experimental purposes. An alloy of vanadium and iron, ferro-vanadium, is added to steel to improve its qualities for many purposes. Steel thus prepared is eminently suited for armour plate, projectiles and machine tools, since not only is it extremely tough and hard but it does not lose this hardness by being heated to a bright red heat and slowly cooled. Vanadic acid is largely used for the production of indelible black dyes and inks. Various pigments used in colouring porcelain and glass also contain vanadic acid.

Carnotite.—Hydrous vanadate of potassium and uranium. Vanadium, 11 per cent.; vanadium pentoxide, 20 per cent. Occurs

in yellow disseminated grains and bunches in sandstone in Colorado, the rocks being leached with nitric acid to obtain the vanadium.

Uses.—One of the chief sources of vanadium and uranium and their salts.

Roscoelite.—Silicate of potassium, vanadium, and aluminium. Vanadium, 15 per cent.; vanadium pentoxide, 28 per cent. In mica-like scales, brown or brownish green. Translucent, soft. G., 2·9.

Uses.—Used as a source of vanadium compounds.

Vanadinite.—Vanadate and chloride of lead. Vanadium, 4 to 11 per cent.; vanadium pentoxide, 8 to 20 per cent. In red or yellow crystals or incrustations. Brittle, soft, opaque. G., 6·8.

Uses.—Used as a source of vanadium compounds, and of metallic lead.

T. 82.—Vanadinite, New Mexico, U.S.A.

ZINC.

Zinc, or spelter, is a common metal which has been known to civilised man for several centuries. It is a blueish white crystalline metal, brittle at ordinary temperature, but malleable and ductile at a little above the temperature of boiling water. It takes a good polish and is unaffected by perfectly dry air, but is rapidly coated in moist air with a greyish white tarnish, which protects the metal from further corrosion. It is readily soluble in dilute acids, and has a specific gravity of 7·1.

Native zinc has been reported to occur in very small quantities, but its occurrence needs confirmation. The sulphide, blende, is a common constituent of veins, whilst the oxide zinkite; the carbonate, smithsonite and hydrozinkite, and the silicates, willemite and hemimorphite are less common ores. Franklinite, an oxide of iron and zinc, occurs plentifully in New Jersey, U.S.A.

Metallic zinc is chiefly used for roofing purposes, either in sheets or as a surface coating upon iron, which is then said to be galvanised. Sheet zinc is also used for various internal ornamental work, lining packing cases, making water tanks and pipes, etc. In plates it is used to prevent corrosion of boilers, also in galvanic batteries, in photo-engraving, etc. Fine shavings of zinc are used to precipitate gold from cyanide solutions; whilst zinc powder is used as a reducing agent in manufacturing organic compounds, as a paint, and in the preparation of zinc salts. Spelter is used for making castings, for desilverising lead, for coating iron and steel, and for making alloys.

Of metallic alloys the most important are brass and bronze, in the preparation of which large quantities of zinc are consumed. Zinc also forms useful alloys with alluminium and with nickel and copper.

Oxide of zinc (zinc white), obtained from the metal or direct from the ore, is a very valuable pigment which has largely replaced

white lead. It is also used as a constituent of many rubber goods. Zinc chloride is used as a disinfectant, and preservative of wood, in refining oils, and in making stearic acid, ether, and parchment paper. Zinc sulphate is used in dyeing, in the manufacture of glue, and the pigment known as lithophone, and as a dryer in oil paints and varnishes. Zinc chromate is used as a pigment. Several zinc salts are used in medicine.

Blende (Sphalerite).—Sulphide of zinc, ZnS. Zinc, 57 to 67 per cent. Crystallised or massive cleavable, granular to compact. Yellow, brown, black; transparent to opaque. Soft, brittle. G. 4·0. Occurs in veins in crystalline and other rocks, also in irregular masses and veins in limestone.

Uses.—The commonest source of zinc and its compounds. Value of this and other zinc ores depends upon percentage of zinc present, and on freedom from lead ores. Ores or concentrates containing over 4 per cent. of lead are practically unsaleable to smelters.

T. 88.—Crystallised Blende, Cumberland, England.
4032.—Massive Blende, Northampton.

Franklinite.—*See* page 35.

Zinkite.—Oxide of zinc, ZnO. Zinc, 74 to 80 per cent. Rarely crystallised, usually massive granular or foliated. Deep red to orange, translucent. Soft, brittle. G., 5·6.

Uses.—A source of zinc. *See* remarks under Blende.

T. 90.—Zinkite, New Jersey, U.S.A.

Smithsonite.—Carbonate of zinc, $ZnCO_3$. Zinc, 42 to 52 per cent. Crystallised or massive granular or earthy, also stalactitic. White or tinted, translucent. Hard, brittle. G., 4·4. Occurs usually in veins and irregular masses in limestones.

Uses.—*See* Blende.

4351.—Smithsonite, Chillagoe, Qld.

Hydrozinkite.—Hydrous carbonate of zinc. Zinc, 55 to 60 per cent. Massive, compact, fibrous, earthy, or stalactitic. White, grey, or yellow; opaque, dull. Soft, brittle. G., 3·7.

Uses.—*See* Blende.

Willemite.—Silicate of zinc, Zn_2SiO_4. Zinc, 48 to 58 per cent. Crystallised, massive, compact, or fibrous. White or tinted, transparent to opaque. Hard, brittle. G., 4·0.

Uses.—*See* Blende

T. 94.—Willemite, New Jersey, U.S.A.

Hemimorphite.—Hydrous silicate of zinc. Zinc, 50 to 54 per cent. Crystallised, stalactitic, fibrous, massive, granular. White or tinted, transparent to translucent. Hard, brittle. G., 3·5.

Uses.—*See* Blende.

T. 93.—Hemimorphite, Laurium, Greece.

ZIRCONIUM.

This rare element was discovered at the close of the 18th century. It is a crystalline metal resembling antimony in appearance and oxidising but slowly in the air. It is soluble in warm acids and has a specific gravity of 4·1.

Zirconium does not occur free in nature; its commonest compound is the silicate, zircon, which occurs in small quantities in granite and other crystalline rocks, and in the sands resulting from their denudation. Zirconium also occurs in several rare silicates, tantalates, etc.

The metal is not applied to any useful purpose, but the oxide (zirconia) is employed in the glowers of Nernst and other lamps, having the property of yielding an intense light at comparatively low temperatures.

Zircon.—Silicate of zirconium, $ZrSiO_4$. Zirconia, 61 to 67 per cent. Usually crystallised, also in rolled grains. Colourless or tinted, transparent to opaque. Very hard, brittle. G., 4·7.

Uses.—Used as a source of zirconia. Some varieties used as a gem, *see* page 68.

5549.—Zircon Sand, Donnelly River.

SILICA AND SILICATES.

Silica, the oxide of the nonmetallic element silicon, is widely and abundantly distributed in the form of quartz (free silica) and various silicates of the metals. It is a colourless, transparent, crystallised substance, which is very hard and infusible and resists the action of most acids.

By far the most important artificial substance containing silica is glass, which is a silicate of sodium and calcium or other metallic base. Hydraulic cement is a silicate and aluminate of calcium. Carborundum, a valuable abrasive, is a carbide of silicon.

Quartz.—Silica, SiO_2, with more or less admixed oxide of iron, etc. Crystallised or massive, compact or granular. Coluorless, white or tinted; transparent to opaque. Hard, brittle to tough. G., 2·6.

Uses.—Largely used as a refractory material and in the manufacture of glass and porcelain. For these purposes and for making carborundum it should be very pure and especially free from iron compounds. Less pure varieties are used as an abrasive, for making mortar, for filters and for a multitude of other purposes. Perfectly transparent, flawless crystals, or masses are used for making lenses and ornaments and are of considerable value.

4669.—Quartz Crystal, Hardy River.

4360.—Pure Quartz Sand, Lake Gnangara.

Diatomaceous Earth (Infusorial Earth).—Hydrous silica with more or less admixed organic matter, clay, etc. Consists of the accumulated remains of minute water plants. Massive, tough, or earthy and friable. White, grey, or black; opaque. Very soft and porous. G., 1·2 in bulk and dry, 0·2 up to 0·8. Occurs in surface or buried beds. Often occurs in beds of lakes and swamps.

Uses.—When calcined artifically or by nature so as to remove all organic matter and moisture, is used for a great variety of purposes. It is largely employed as an abrasive, especially as a constituent of polishing powders and soaps, for this purpose it should be as free as possible from admixed sand or grit. Owing to its great porosity it is largely used as an absorbent, especially for nitro-glycerine forming dynamite; for disinfectants, etc. Its utility for these purposes depends upon its absorbent capacity, and in the case of dynamite, upon the presence of many closed spaces in the individual diatom skeletons, and its practical freedom from alumina or lime. Its porosity, lightness, infusibility, and low conductivity for heat make it a valuable heat insulator for refrigerating chambers and wagons, for safes, boiler and steam-pipe coverings, "refrigerating" paints; and as a constituent of fire-resisting cements and bricks. The purest varieties are used also for making soluble glass and other glasses; and as an adulterant of rubber. For most purposes diatomaceous earth should be as free as possible from alumina, lime, iron oxide, and alkalies; and should be highly porous and absorbent.

4361.—Crude wet Diatomaceous Earth, Lake Gnangara.
4365.—Calcined Diatomaceous Earth, Lake Gnangara.
4468.—Crude Diatomaceous Earth, Little Badgerup Lake.
5052.—Crude Diatomaceous Earth, Cooma, N.S.W.

Asbestos.—This is a name applied both in commerce and science to several silicates characterised by a finely fibrous structure. The chief varieties are Amianthus, Chrysotile, Picrolite, and Actinolite.

Amianthus.—Hydrous silicate of magnesia. In long, fine, silky fibres, very flexible and tough. White or pale green, opaque. Occurs in veins and pockets in serpentine.

Uses.—This is the most valuable variety of asbestos owing to the length, evenness, flexibility and toughness of the fibres, the ease with which they can be separated from one another, and their great resistance to heat and poor conductivity. It is woven into packing for pistons, valves, and other parts of engines; into rope for suspending crucibles, etc., in contact with fire, and for use in theatres and acid works; into cloth for theatre screens, colliery doors, etc. The scrap is used for the same purpose as chrysotile and picrolite.

Chrysotile.—Hydrous silicate of magnesia. In short ($\frac{1}{4}$ inch to 4 inch) soft fibres, very flexible and tough. Pale green, opaque. Occurs in veins in serpentine.

Uses.—This forms the great bulk of the world's asbestos. It is woven into yarn and cloth for packings, etc. Also made into felt for fireproof screens, etc. Used also for covering steampipes, etc., for lining for safes and many other purposes. Less valuable than Amianthus.

1010.—**Asbestos, var. Chrysotile, near Tambourah.**

1821.—**Asbestos, var. Chrysotile, Metford, Canada.**

Picrolite.—Hydrous silicate of magnesia. In short or long irregular fibres, very soft and brittle and of low tensile strength. Pale green, opaque. Occurs in veins in serpentine.

Uses.—This is one of the commonest but least valuable varieties of asbestos. It cannot be woven but is used as a base for heat-proof paints and cements, boiler coverings, etc.

5517.—**Asbestos, var. Picrolite, Pickering Brook.**

Actinolite.—Silicate of calcium, magnesium, and iron. In short or long irregular fibres, hard, brittle, and very difficult to separate. White or pale green, opaque. Occurs in veins and nests in basic igneous rocks.

Uses.—Of little value but can be used for same purposes as Picrolite.

1098.—**Asbestos, var. Actinolite, Ballagundi.**

The market value of asbestos depends upon the length, strength, evenness, infusibility, and flexibility of the fibres, and the ease with which they can be separated from one another, and also upon its freedom from admixed rock, iron oxide, etc. Fresh uses are continuously being found for asbestos, but so far the supply has been so well kept up that the price of the mineral has decreased considerably within recent years. Before marketing, asbestos is graded according to length into long, over $\frac{3}{4}$inch; medium, $\frac{1}{2}$ to $\frac{3}{4}$inch; short, under $\frac{1}{2}$inch.

Mica.—Like asbestos, this name is applied both commercially and scientifically to several distinct silicate minerals, all of which are characterised by a very perfect cleavage which enables them to be split into thin elastic plates. The most important species are Muscovite, Phlogopite, Biotite, and Lepidolite.

Muscovite.—Common or white mica. Silicate of aluminium, potassium, and hydrogen. Crystallised or foliated massive. Colourless or tinted; transparent. Soft. G., 2·8. Laminæ flexible, elastic, tough, and very infusible. Occurs in pockets or veins in granite or gneiss, especially in pegmatite veins.

Uses.—This is the most useful variety of mica. In sheets at least 2 inches x $1\frac{1}{2}$ inch, is used for windows of stoves and furnaces, for funnels for lamps and gaslights, for skylights and compass-covers. Large quantities of sheet mica are used for electrical insulations. The scrap mica left after trimming the mineral into sheets is used for a variety of purposes. It is cemented into sheets and used for electrical insulation, under the name of "micanite."

When ground, it is used as a lubricant, as a constituent of some brands of dynamite, of various piston packings, fire-resisting paints, and insulating compounds, in the manufacture of lustrous hair powder, and mixed with plaster of Paris for moulds for castings. It is also used to a certain extent in decorative work, both in sheets and powder. An excellent non-conducting covering, which is both flexible and fireproof, is formed by a quilting finely powdered scrap between galvanised wire netting.

5188.—Mica, var. Muscovite, Macdonnell Range, S.A.

Phlogopite.—Amber mica. Fluo-silicate of aluminium, magnesium, and potassium. Crystallised or foliated massive. Usually amber, sometimes colourless or tinted variously; transparent to translucent. Soft. G., 2·8. Laminæ flexible, elastic, tough, and infusible. Occurs in veins or pockets in serpentine, crystalline limestone, or dolomite.

Uses.—*See* Muscovite.

Biotite.—Black mica. Silicate of aluminium, magnesium, iron and potassium. Crystallised or laminated massive. Black, green, yellow, or brown; transparent to opaque. Soft. G., 2·8. Laminæ flexible, elastic, tough, and infusible. Occurs in veins and pockets in granite and other crystalline rocks.

Uses.—Owing to low electric resistance, is not of much value for insulating purposes. Used for most other purposes described under Muscovite.

Lepidolite.—Lithia mica. Fluo-silicate of aluminium, potassium and lithium. *See* page 37.

Uses.—Owing to easy fusibility, cannot be used for any of the purposes to which other micas are put, except the ornamental purposes. Chiefly used as a source of lithium salts.

556.—Mica, var. Lepidolite, Londonderry.

777.—Mica, var. Lepidolite, trimmed for market, Londonderry.

Mica is marketed in two forms, viz., "sheet," consisting of thin rectangular blocks of certain standard sizes, varying from 2 inches by 1½ inches up to 8 inches by 10 inches or more; and "scrap," the small pieces left after punching out the sheets from the crude mineral. The latter is of very little value, something like 1d. to 2d. a pound. The value of sheet mica depends upon the size of the sheet (varying from 3s. per lb. to £2 10s. per lb.), the ease with which it can be split up, its softness, flexibility, and freedom from wrinkles and blemishes. When used as a substitute for glass its transparency and colour are important points. For electrical purposes its resistance to heat and electricity are of importance.

Talc (Steatite, Soapstone).—Hydrous silicate of magnesium. Rarely in tabular crystals, usually massive, foliated, granular, compact, or fibrous. White or green; translucent. Very soft, sectile. G., 2·7. Occurs as rock masses and in veins and beds.

Uses.—When powdered, is largely used as a filling for paper; for this purpose the fibrous form is the best. Also for fire-proof paints, electric insulators, steam-pipe and boiler coverings, foundry facings, toilet powders, lubricants, and as a base for dynamite and cheap soap. Compact talc is cut into pencils, fire-bricks, hearthstones, footwarmers, etc.

4294.—Fibrous and massive talc, Broad Arrow.

Feldspar.—This name is applied to a group of minerals closely related to one another in occurrence, properties, and composition; being silicates of aluminium with potassium, sodium, or calcium. The chief varieties from a commercial point of view are orthoclase and albite.

Orthoclase.—Silicate of aluminium and potassium. Crystallised with a perfect cleavage or massive. Colourless, white, or tinted; transparent to opaque. Hard; brittle. Occurs in workable deposits chiefly in pegmatite veins.

Uses.—Chiefly used as a constituent of china, porcelain, tiles, and certain varieties of glass. Also used as an abrasive especially in polishing-soaps. Small quantities used in dentistry. Has been proposed to utilise it as a source of potash salts.

378.—Feldspar, var. Orthoclase, Londonderry.

24.—Feldspar, var. Orthoclase, Northampton.

Albite.—Silicate of aluminium and sodium. Crystallised with perfect cleavage, massive granular or lamellar. White or tinted; transparent to opaque. Hard; brittle. Occurs in workable deposits chiefly in pegmatite veins.

Uses.—*See* Orthoclase.

5288.—Feldspar, var. Albite, Ravensthorpe.

5307.—Feldspar, var. Albite, with tin ore, Moolyella.

Other varieties of feldspar could be utilised for a similar purpose were workable deposits of them available. For market the ore must be carefully hand-picked to remove all associated minerals especially those containing iron. Feldspar containing more than a trace of iron is not suited for making porcelain or glass. A small unavoidable admixture of clean, colourless quartz is no great drawback to the mineral.

Garnet.—This group of minerals is characterised by a similarity of crystalline form, chemical composition, and occurrence. The commonest species are almandite and andradite.

Almandite.—Silicate of ferrous iron and aluminium. Crystallised, massive, granular, or compact. Red or black; transparent to opaque. Hard, brittle, or tough. G., 4·0. Occurs in granite or other rocks, or in beach or river sands.

Uses.—Used largely as an abrasive. Fine clear specimens make gems. *See* page 69.

4797.—Garnet in granite, Upper Bowes River.

5315.—Garnet, near Marble Bar.

4794.—Garnet sand, mouth of Bowes River.

Andradite.—Silicate of calcium and ferric iron. Crystallised, massive, granular, or compact. Black, green, yellow, brown; transparent to opaque. Hard, brittle, or tough. G., 3·9. Occurrence and uses same as for almandite.

The value of garnet as an abrasive depends upon its hardness and toughness, and its freedom from mechanically admixed impurities. Other varieties of garnet, if found in workable quantities, could be used for the same purpose as almandite and andradite.

GEMS AND ORNAMENTAL STONES.

Gems, which include the most valuable of all minerals, may be defined as those varieties of mineral species which possess such striking and permanent beauty as to make them desirable articles of personal adornment. The value of gems depends upon their freedom from flaws or blemishes, the shade of colour they possess, and the permanency of that colour when exposed for long periods to light and air; their degree of transparency (except in the case of perfectly opaque gems such as turquoise); their hardness, and finally their rarity. The following is the approximate order of value of precious stones:—Pearl, Ruby, Diamond, Emerald, Sapphire, Oriental Cat's Eye, Opal, Turquoise, Alexandrite.* Other ornamental stones, such as Tourmaline and Jade, are classified as "semi-precious," owing to their inferior rarity and value. In the following pages the order followed under the headings of "Precious Stones" and "Semi-precious Stones" has been determined by the chemical and mineral nature of the gems. In each case the general description given is that of the most valued type, and is in more detail than those of less valuable minerals given in this brochure.

Precious Stones.

Diamond.—Pure carbon, C. Crystallised in octahedra and other forms of the isometric system; also in water worn pebbles. Transparent. Most valuable are colourless, red, or blue; of less value those that are yellow, green, or brown. Hardness, 10; G., 3·5. Occurs in basic igneous rocks and in alluvial deposits. At the present day South Africa supplies the greatest part of the total demand for this gem. Small diamonds have been found in conglomerate at Nullagine, in this State.

Ruby.—Variety of Corundum. Oxide of aluminium, Al_2O_3. Crystallised in hexagonal pyramids, more or less modified; also in water-worn pebbles. Transparent. Pigeon-blood red; less valued gems are of other shades of red. H., 9.; G., 4·0. Occurs in Crystalline limestone and in alluvial deposits. Chiefly derived from Burmah.

Sapphire.—Variety of Corundum. Oxide of aluminium, Al_2O_3. Form and other characters, except colour, as for Ruby. Colour, corn-flower blue or rarely rich green; other shades of blue are less admired. Occurs in crystalline limestone, basic igneous rocks, and mica-schist, also in alluvial deposits. The chief sources of sapphires are Siam, Burmah, Cashmere, and Ceylon.

Sapphires and other gem stones, Inverell, N.S.W.

* E. W. Streeter, Precious Stones and Gems.

Emerald.—Variety of Beryl. Silicate of beryllium and aluminium, $3BeO.Al_2O_3.6SiO_2$. Crystallised in hexagonal prisms. Transparent; rich green in colour. H., 7·5. G., 2·7. The chief source of the emerald is Colombia, where it occurs in pockets in a limestone. Elsewhere they are found in mica-schist, talc-schist, and topaz rock.

Oriental Cat's-eye.—Variety of Chrysoberyl. Oxide of beryllium and aluminium, $BeOAl_2O_3$. Crystallised in complex forms of the orthorhombic system; more usually in water worn pebbles. Translucent; colour, from pale yellow to dark brown, and pale green to deep olive. Chatoyant; characterised by a movable internal opalescent band of white or rarely yellow light. H., 8·5. G., 3·8. Chief source is Ceylon, where it is found in river gravels.

Alexandrite.—Variety of Chrysoberyl. Oxide of beryllium and aluminium, $BeO.Al_2O_3$. Crystallised usually in twins of the orthorhombic system; also in rolled pebbles. Transparent. Colour, emerald green, changing in artificial light to raspberry red. Very rarely chatoyant. H., 8·5. G., 3·7. Occurs in mica-schist in the Ural mountains; and in river gravels in Ceylon.

Opal.—Precious opal is a variety of common Opal. Hydrated silica, $5SiO_2.2H_2O$. No crystalline form; occurs massive, filling small veins and hollows in the parent rock. Translucent. Colour, milky white, exhibiting a magnificent play of prismatic colours on turning through a small angle. Rich red tints are most highly prized. Some opals lose their colour after exposure for some little time, and are therefore of very little value. H., 5·5 to 6. G., 2·1. The best opals come from Queensland and New South Wales where they occur filling small veins in sandstone and trachyte and steam holes in the latter. Found also under similar conditions in Hungary and America.

4885.—Opal, Eromanga, Qld.

Turquoise.—Hydrated phosphate of aluminium, copper, and iron; formula uncertain. No crystalline form; occurs massive in veins or nodules. Opaque. Colour, sky-blue, greenish blue, or green, the first-named being the most valued. Many turquoises fade so easily as to be practically valueless. H, 6. G., 2·7. Chiefly obtained from Persia, where it occurs in veins and nodules in trachyte and slate. Occurs largely in the United States and elsewhere in porphyry, trachyte, slate, and sandstone.

Semi-precious Stones.

Zircon or **Hyacinth.**—Silicate of zirconium, $ZrO_2.SiO_2$. Crystallised in combinations of pyramid and prism of the tetragon system; also in water-worn pebbles. Transparent; crimson, yellowish-red, amber yellow. H., 7·5. G., 4·4 to 4·8. Ceylon and New South Wales yield the best hyacinths. They occur in river gravels or in situ in syenite, granite, and other crystalline rocks.

Peridot (Precious Olivine).—A variety of Chrysolite. Silicate of iron and magnesium, $2(MgFe)O.SiO_2$. Occasionally crystallised in combinations of orthorhombic prism and pyramid; usually in water-worn pebbles. Transparent; yellowish-green in colour, the deeper the tint the more valuable the stone. H., 6·5. G., 3·4. Occurs chiefly in river gravels in the Levant, Brazil, and elsewhere.

Tourmaline.—Transparent variety of ordinary tourmaline. Composition very complex; a silicate of aluminium, boron, iron, etc. Crystallised in combinations of prism and pyramid of hexagonal system; also in water-worn pebbles. Transparent; colour red, pink (*Rubellite*), green of various shades, blue (*Indicolite*), yellow. H., 7·5. G., 3·1. Occurs chiefly in granitic rocks carrying lithia mica; also in river gravels. Obtained from Siberia, Brazil, United States, Ceylon, Kangaroo Island, etc. Imperfect specimens have been received from Ravensthorpe in this State.

5293.—Rubellite, Ravensthorpe.

Topaz.—Precious variety of ordinary Topaz. Fluosilicate of aluminium, $Al_2O_3(O.F_2).SiO_2$. Crystallised in combinations of orthorhombic prism and pyramid, with perfect basal cleavage; also in water-worn pebbles. Transparent, usually wine-yellow, but also light and dark red, pale blue, pale violet, or colourless, H., 8. G., 3·5. Occurs usually in gneiss, granite, or pegmatite, and in river gravels. Gem topaz comes from Brazil, Siberia, United States, etc. Pale blue topaz has been collected at Londonderry in this State.

4450.—Blue Topaz, Londonderry.

Aquamarine and **Beryl** are transparent varieties of common Beryl, the former of a pale green or pale blue colour, the latter yellow. Except in colour they are identical with Emerald, *q.v.*

Garnet.—Gem varieties of several mineral species belonging to the Garnet Group. Three species are used as gems:—*Almandine (Carbuncle)*, Silicate of aluminium, and ferrous iron, $Al_2O_3.3FeO.3SiO_2$. Claret coloured and most valuable of garnets. *Pyrope*, silicate of aluminium, magnesium, and iron; $Al_2O_3.3(MgFe)O.3SiO_2$. Blood red. *Essonite* (sometimes called *Hyacinth*). Silicate of aluminium and calcium. $Al_2O_3.3CaO.3SiO_2$. Yellow, orange, or brown.

Garnets are found crystallised in forms of the isometric system, the commonest form being the dodecahedron; also in water-worn pebbles. Transparent or semi-transparent; colours as above. H., 7 to 8. G., 3·5 to 4·1. Occurs usually in granite, gneiss, mica schist, or chlorite schist, or in river gravels. Very widely distributed. Fine coloured garnets have been received from near Uaroo in this State.

Spodumene.—Transparent variety of ordinary spodumene. Silicate of aluminium and lithium $Al_2O_3.Li_2O.4SiO_2$. Crystallised in combinations of prism and pyramid of monoclinic system, with strong prismatic cleavage. Transparent. Colour greenish yellow,

rich green (*Hiddenite*), amethyst (*Kunzite*). H., 7. G., 3·1. Occurs usually in granite, pegmatite, or gneiss. Chief sources are Brazil and North Carolina.

Jade (Greenstone).—Partly a variety of Jadeite, which is a silicate of aluminium, sodium, and calcium, $Al_2O_3.(Na_2Ca)O.4SiO_2$. Partly a variety of Actinolite, a silicate of calcium, magnesium, and iron, $CaO.3(MgFe)O.4SiO_2$. Occurs massive with internal crystalline structure. Translucent; dark or light green, yellowish green. H., 6 to 7. G., 3·0. to 3·3. Occurs usually in rounded masses in river beds, or in weathered serpentine rock masses. Chief sources, China, Burmah, New Zealand, Central America.

Crocidolite.—A mixture of anhydrous and hydrous silica with more or less silicate of iron, resulting from the partial or complete alteration of true Crocidolite, which is a silicate of iron and sodium. Compact massive with greater or less fibrous structure. Translucent to opaque, chatoyant. Colours, indigo with light blue ray (*Hawk's Eye*); brown with yellow ray (*Tiger's Eye*); yellow with pale yellow ray; pale green with white ray. H., 6 to 7. G., 2·7 to 3·1. Occurs in veins in igneous rocks in Griqualand and elsewhere in South Africa. Excellent specimens have been received from Yarra Yarra Creek, Murchison District, in this State.

5063/4.—Crocidolite (Tiger's Eye, etc.), Yarra Yarra Creek.

Chalcedony.—Massive cryptocrystalline variety of quartz, SiO_2. Appearance subject to wide variation from the presence of small proportions of impurities. The chief ornamental varieties are: *Carnelian*, translucent of various shades of red, often striated. *Agate*, translucent and variegated, various shades of yellow, red, brown, purple, etc. *Onyx*, translucent, in plain parallel bands of white and black, or brown. *Heliotrope* or *Bloodstone*, translucent, green with blood red spots. *Jasper*, opaque, in bands of bright red, yellow, brown, white, and black. The hardness of the various varieties of chalcedony is 7, specific gravity 2·6. Chalcedony occurs in nodules in ancient lavas, in veins in various rocks, and in pebbles in streams, etc.

3695.—Jasper, Marble Bar, Coongan River.

Moonstone.—Variety of Orthoclase. Silicate of aluminium and potassium, $Al_2O_3.K_2O.6SiO_2$. Crystallised in monoclinic prisms; usually in water worn pebbles. Semi-transparent, opalescent. Colourless or faintly blue. H., 6. G., 2·6. Usually found in pebbles in streams in granite country, especially in Ceylon. Some good moonstones have been found at the mouth of the Bowes River, in this State.

4792.—Moonstone, mouth of Bowes River.

Sunstone or Aventurine.—Variety of Oligoclase. Silicate of aluminium, sodium, and calcium, $2Al_2O_3.Na_2O.CaO.8SiO_2$. Crystallised in forms of the tryclinic system. Translucent, brown with golden spangles. H., 6. G., 2·7. Occurs in igneous rocks, especially in Norway.

Aventurine, Tvedestrand, Norway.

MINERAL WATERS.

Mineral waters may be described as those natural spring waters which contain in solution either constituents rarely found in surface waters, or else exceptionally large proportions of mineral matter of any kind. They are of value either for medicinal purposes or else, owing to their pleasing taste, for table use.

Medicinal waters are chiefly characterised by the presence of magnesium salts, iron salts (Chalybeate waters), lithium salts, sulphides, or sulphates of soda and potash. Of these probably those containing lithium or iron would be found the most valuable commercially. Magnesian waters are common everywhere especially in the interior of Western Australia. They are unmarketable except when they bear the name of some well known European spring such as Friedrichshall, Kissingen, etc.

Table waters of good quality are in considerable demand. They should be sparkling and of good flavour and should therefore contain free carbonic acid and alkaline carbonates, with comparatively little salt, magnesium compounds, or alkaline sulphates. It is essential that they be quite free from sulphuretted hydrogen or sulphides, whilst the presence of some lithium is a decided advantage. The following table gives the composition of the only Australian mineral waters at present utilised, and will serve to show what composition is desirable in a water for the Australian market:—

Source.	Helidon Spa, Helidon, Q.	Zetz Spa, Ballimore, N.S.W.	Koomah Spa, Cooma, N.S.W.	Mittagong Spa, Mittagong, N.S.W.
Use.	Table.	Table.	Table.	Chalybeate medicinal.
	Parts per 1000.			
Potassium chloride ...	...	...	...	·0291
Sodium chloride ...	·0428	·0988	·072	·0308
Magnesium chloride ...	...	...	...	·0185
Sodium bicarbonate ...	4·7883	2·6157	·647	...
Potassium bicarbonate	...	·1833	·245	...
Lithium bicarbonate ...	·0704	·0007	*nil*	...
Magnesium bicarbonate	·0837	·1337	·320	·0320
Calcium bicarbonate ...	·1701	·1625	·774	·0291
Strontium bicarbonate	...	trace	strong tr.	...
Iron bicarbonate ...	...	·0100	*nil*	·0855
Silica	·0041	·0040	·008	...
Alumina	...	trace	trace	...
Free carbonic acid gas	abundant	abundant	abundant	present

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1905.

WESTERN AUSTRALIA.

GEOLOGICAL SURVEY.

BULLETIN No. 20.

FURTHER REPORT

ON THE

GEOLOGICAL FEATURES AND MINERAL RESOURCES

OF THE

PILBARA GOLDFIELD,

BY

A. GIBB MAITLAND,
Government Geologist.

Issued under the authority of the Hon. R. Hastie, M.L.A., Minister for Mines.

With Three Geological Maps, Four Mining Plans, and 13 Figures.

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PREFATORY NOTE.

THIS report makes a further instalment to the descriptions of those mining centres of the Pilbara Goldfield referred to in Bulletin No. 15.

This report includes full details with reference to the Nullagine, Warrawoona, and Marble Bar fields, and is accompanied by geological and mining maps, without which the descriptive portions would be well-nigh unintelligible.

As in the previous season's field work, I was associated throughout with Mr. H. W. B. Talbot, Field Assistant, who rendered important assistance in the preparation of the various maps and plans.

The Index to names, places, reefs, etc., occurring in the report has been prepared by Mr. P. J. Atkins, Clerk of the Geological Survey.

A. GIBB MAITLAND,

Government Geologist.

Geological Survey Office,

Perth, 1st June, 1905.

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FURTHER REPORT

ON

The Geological Features and Mineral Resources

OF THE

PILBARA GOLDFIELD.

PART I.

Descriptive Geology.

Arriving at Port Hedland on the 30th of June in order to continue the examination of the different mining centres left untouched during the previous season, I travelled by coach as far as Marble Bar, and joined the camp, which was in charge of Mr. Talbot, on the 5th of July.

Leaving the camp at Duffer's Creek, we travelled northwards as far as the junction of Talga Creek and the Talga River. From the camp a conspicuous hill was observed 420 feet by aneroid in height and bearing 56 degrees from it. This hill forms the summit of a very long range extending northwards from the Talga Talga workings; it is composed of transmuted basic igneous rocks, intersected by laminated quartz veins. These foliated rocks dip westward at angles of from 40 to 60 degrees; associated with them are some green rocks, which weather very much like limestones; they are, however, identical with those basic igneous rocks, the original minerals of which are replaced by carbonates, so common in many parts of the district.

From this camp we travelled to a gorge known as Kitty's Gap, excavated in that laminated jaspideous quartzite, which extends from Doolena Gap to Bamboo. From camp to the gap, the whole country traversed is greenstone and its derivatives, except for about a mile of granite, which in all probability is an off-shoot from the Moolyella mass.

After getting clear of the Gap, the northern face of the range was skirted as far as Coppin's Gap. The country at the foot of the northern face of the range exposes a gneissic granite, the strike of the foliation of which is parallel to that of the laminated quartzite which makes up the range.*

* Bulletin No. 15, pp. 25, 26.

From Coppin's Gap we travelled northwards towards the point of a conspicuous range of hills which lay between us and Bamboo Creek. The highest summit of the hill rises to a considerable height above the plains, which are everywhere underlaid by granitic gneiss and allied rocks. The rocks forming the hills consist of volcanic agglomerate dipping at angles of about 20 to 30 degrees to the east, and passing beneath the sedimentary beds of what there are good reasons for believing to be the equivalents of the Nullagine Series. Associated with these agglomerates are greenish grey beds of either lava or ash. Travelling across to Bamboo Creek, strata on a somewhat higher horizon are traversed; they consist of coarse conglomerates, and fine-grained sandstones, some beds of the latter of which have been quarried to a limited extent. Some of these conglomerates and grits are traversed by vertical quartz veins, some of which are of considerable horizontal extent. The general strike of these "buck-looking" quartz veins is 16 degrees. From our camp at a fine pool of water near a boundary fence (? Coppin's) to the now all but deserted township of Bamboo, the road follows the edge of the top of volcanic beds of the Nullagine Series.

The country in the more immediate vicinity of this centre having been previously fully described* need not be repeated.

From Bamboo to the foot of Mount Edgar, *via* Jones' Well, the country is made up of granite of the Moolyella type, intersected by dykes of felsite and diabase in addition to quartz veins.

Mount Edgar, one of the most prominent landmarks in the vicinity, rises to a height of about 300 feet above the base, and consists of a bluish grey basic rock [5753] in the form of a dyke. In the vicinity of Mount Edgar, the staple formation of the district (granite) is traversed by two sets of felsite dykes, one set with a general strike of north 30 degrees east, and the other north 30 degrees west. Both of these sets of dykes are traversed almost at right angles by quartz reefs, in this respect they are somewhat analogous to the system of quartz reefs and dykes of the Charters Towers Goldfield in Queensland, with which I am familiar.

From Mount Edgar, we steered across country for Warrawoona, crossing *en route* a very conspicuous greenstone dyke, at the foot of the northern side of which the Talga River flows.

This dyke, which has a general bearing of 334 degrees and 163 degrees, rises to a considerable altitude above the plain, and forms a very conspicuous feature in the landscape. So far as can be seen, the dyke is vertical and attains a thickness of about 20 feet; it traverses granite country. Several other parallel dykes of a somewhat similar nature can be seen in the vicinity.

Between this point and Warrawoona, two other parallel dykes are crossed. The granite country ends about a mile or so north of Warrawoona, and gives place to those beds, a detailed description of which is given on a later page.

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* Bulletin No. 15, pp. 26, 51-61.

The mapping and examination of Warrawoona, having been completed, we struck camp and travelled in the direction of Yandicoogina as far as Gum Well. The country between the camp and the well is underlaid by granite, which has a rude foliation, the general strike of which is parallel to that of the schists, which forms the high ground of the range, near the foot of which the main road traverses. At a point about two miles west of the well, a very prominent diabase dyke is crossed, in addition to two others of much smaller dimensions; the larger dyke in all probability represents the extension of the one crossed between Mount Edgar and Warrawoona. The large dyke near Gum Well makes a very prominent feature in the landscape, and can be followed by the eye across country for a considerable distance. A traverse on foot was made from Gum Well to the range, and at one spot the large coarse-grained diabase dyke was shifted for a horizontal distance of 120 feet west by a fault bearing 112 degrees. This fault is now occupied by a quartz reef. A parallel diabase dyke of smaller dimensions has also been subject to the same amount of western displacement.

From Gum Well, a conspicuous Gap in the main range can be observed. The position of the Gap is fixed by the following bearings:—Gum Well, 31 degrees 30; Mount Edgar 41 degrees; Trig. Station G. 23, 276 degrees; and Horrigan's Peak, 302 degrees.

The Gap has been carved out of a bold quartz reef, which measures from 30 to 40 feet in width, and is of very considerable horizontal extent; for it has a length of about four or five miles in a direction of 118 degrees, and about a mile in the direction of 298 degrees. The quartz reef is evidently along a line of fault (?) which separates the granitic rocks from the Warrawoona Beds, which latter at this point occupy a width of about two miles. The large greenstone dyke previously alluded to abuts abruptly against the quartz reef of the Gap, but does not cross it. The Trig. Station G. 23 is formed of another large quartz reef, identical with that forming the Gap, and equally wide and persistent longitudinally. Both form remarkably pronounced features in the landscape.

The country between Gum Well and Yandicoogina is of granite intersected with numerous greenstone dykes.

From Yandicoogina, exigencies of travel rendered it necessary to travel as far as the De Grey (Nullagine) River *via* the main Elsie Road.* We camped on a creek, at an altitude of about 200 feet above Yandicoogina, which flowed in a general direction of north 70 degrees east. Advantage was taken of the short spell of daylight after arriving to examine the country in the vicinity. About three miles north 70 degrees east from camp was a conspicuous escarpment, the summit of which seemed to afford a good opportunity of examining the surrounding country, and a traverse was made in that direction.

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* Bulletin No. 15, p. 27.

On the eastern bank of the creek, upon which the camp was pitched, is a good exposure of sandstones and shales (Nullagine Series) dipping at 20 degrees in a direction north 30 degrees east and traversed by several small faults. Sandy beds cover the surface of the country as far as the foot of the escarpment.

The bed forming the summit of the hill is a thin bed of quartzose conglomerate, containing pebbles and fragments of those laminated quartz veins so conspicuous in other portions of the district. The general dip of these sedimentary rocks which must, as seen from the hilltop, occupy a large area of country, is in the direction 228 degrees at angles varying from 8 to 10 degrees.

Having reached the De Grey (Nullagine) River, it was followed to the junction of Cook's Creek. At a point about six or seven miles in the river above the crossing of the Elsie Road, granite emerges from beneath the sedimentary rocks and occupies the country for some considerable distance. The granite is traversed by numerous quartz veins which have a general bearing of about 174 degrees.

Cook's Creek was followed up to the point at which it is joined by Mosquito Creek, passing the Black Range of the maps *en route*. The Black Range is a long razor-backed ridge of laminated quartz of the usual type. Having camped on Mosquito Creek some miles below the township, a visit was paid to the Parnell Mine.* The country between the camp and the township of Mosquito showed the staple formation to consist of highly-inclined grits, sandstones, and shales (or slates), with numerous quartz veins along the bedding planes (Mosquito Creek Beds).

In the vicinity of the lower (Mosquito Creek) well, two conspicuous rugged hills of granite (?) rise from amongst the sedimentary beds. From a distance these hills bear a remarkable resemblance to the granite hills of Mosquito township,† although the area these rocks occupy is not nearly so great as at the township.

From the camp at Mosquito Creek we travelled along the old 40-Mile Road to the crossing of Sandy Creek, which was followed down to its junction with the Nullagine River. The whole section down to the Nullagine River showed the staple formation to be of grits, shales, and conglomerates (Mosquito Creek Series) inclined at high angles. Where Middle Creek joins Sandy Creek is a vertical bed of fine-grained conglomerate.

The Nullagine (De Grey) River was followed up to the township of Nullagine, and the staple formation consisted of highly-inclined sedimentary rocks of the Mosquito Creek Series. On the western bank of the Nullagine River, at the junction of Taylor's Creek, is a large dyke of gabbro, striking about 230 degrees. The dyke, which in all probability has some intimate connection with that which makes such a prominent feature in the geology of the township of Nullagine, is about half-a-mile in width at this point.

* Bulletin No. 15, p. 80. † Loc. cit., p. 78.

Having completed the mapping of Nullagine, a full description of which is given on a later page, we followed the main road to Marble Bar, passing the almost deserted mining centre of Wyman's Well *en route*. The country round Wyman's Well, originally known as Salgash, is identical in its geological features with Warrawoona, of which it merely forms the westward extension.

A twelve-acre lease, the Phœnix G.M.L. 624, owned by Messrs. Anderson and party, and a three-men's quartz claim owned by Messrs. Swanson and Morris Bros., represent the mining activity prevailing.

Marble Bar was reached on the 29th of September.

PART II.

Descriptions of Individual Mining Centres.

A.—NULLAGINE.

(*With a Geological Sketch Map and Section, and a Plan of the Nullagine Conglomerates Gold Mines.*)

The mining centre of Nullagine is situated 55 miles to the north-north-west of Marble Bar, upon the Nullagine River, about 90 miles above its junction with the Oakover; its relative position is shown on the Locality Map of the Pilbara Goldfield, which forms the frontispiece to this report.

Interest attaches to this district on account of the occurrence of gold in certain sedimentary rocks, which bear a close resemblance to the auriferous conglomerates of the Rand (South Africa), better known as the Banket deposits. These (Nullagine) auriferous conglomerates, which seem to form lenticular masses, occur in the basal members of the Nullagine Series* as developed in the ranges to the north-west of the township.

It being an important problem in economic geology to ascertain the extent, etc., of these auriferous conglomerates, as well as the quartz reefs in the underlying series of beds, a belt of country embracing what is, as at present understood, the productive area was mapped upon the scale of 20 chains per inch. The ground covered by this work comprises a belt of country about four miles in length and breadth, which is depicted upon the Geological Sketch Map (Plate I.).

As by far the larger portion of this area was practically a blank upon any of the existing maps, operations had to be commenced by preparing a plan of the vicinity of the mines. This work was accomplished by the aid of a plane table and tape measure; it would, however, have been a decided advantage had time permitted of a contour map of the district being prepared. The local representatives of the British Exploration Company, the principal lease owners in the vicinity, courteously placed at my disposal their topographical plan of the Conglomerate Mines; a reduced copy of this, embodying some geological additions by myself, forms Plate II.

A comparison between this map and the 40 chain lithograph, L 76, issued by the Department of Mines, discloses the fact that considerable violence had to be done to the position of the

* Preliminary Report on the Geological Features and Mineral Resources of the Pilbara Goldfield, by A. Gibb Maitland. Geol. Surv. Bull. 15. Perth: By Authority: 1904, p. 10.

Nullagine River. On lithograph, L 76, it will be noticed that there are two Nullagine Rivers, the most northerly approximately parallel to the Marble Bar Telegraph Line, and the other skirting the northern boundary of the extinct leases 57L and 58L. The true course of the river is that shown on the Geological map.

It is essential, in the public interest, that at any rate the principal water-courses in mining districts especially, should be traversed and their position laid down on the published maps with such a degree of accuracy as the scale employed will admit. Tacheometric methods afford a reliable, cheap, and accurate method of this class of work being carried out expeditiously. A great deal of time and labour is involved in preparing topographical maps, upon which the areas of the different formations, the geological boundaries, the trend of the outcrops of the different ore deposits, etc., could be delineated, which could be much more profitably expended by a geologist in other directions.

In both its physical and geological aspects, the district falls naturally into two distinct portions, which lie respectively to the north-west and south-east of the Nullagine River.

The north-western portion is that occupied by the sandstones, grits, conglomerates, and interbedded volcanic rocks of the Nullagine Series. This series, which presents a plateau-like appearance, exhibits a bold escarpment when viewed from the south-east, and certain of the harder beds stand out in bold relief, presenting mural faces at different levels. The tableland has been carved out into deep canon-like gorges and ravines, of which Beaton's Creek, and the One Mile Creek, are typical examples. The course of many of these creeks, and their tributaries appears to have been in the main determined by the trend of the system of master joints, by which the Nullagine Series has been intersected. An excellent example of this rectangular system of jointing occurs in Beaton's Creek about a mile and a-half above its junction with the Nullagine River, just within the western border of the geological map.

The greater part of the country lying to the south-east is formed of an open rolling plain, the monotony of which is broken by a very conspicuous serrated ridge of gabbro (?). This dyke lies about two miles to the west of the township of Nullagine. The Nullagine River cuts through the ridge at a point about three miles below the township. This gabbro dyke rises to a considerable height above the level of the surrounding country and forms a very conspicuous feature in the landscape. This plain is underlaid by the rocks of the Mosquito Creek Series, which formation carries all the auriferous reefs yet worked in the district.

The whole of the country lies within the watershed of the Nullagine River and its tributaries; the two most important of which are Beaton's and Kadjebut Creeks.

History.

Very little appears to have been officially recorded of the early history of the Nullagine district. It seems, however, that the first discovery of gold at Nullagine was made by Mr. N. W. Cook, in the year 1886, as a reward for which he received, two years later, a sum of £250 from the Government.

The spot at which the original find was made lies at the western extremity of a long, narrow, laterite tableland, in close proximity to several quartz reefs; the position of this spot is indicated on the Geological Sketch Map of Nullagine. (Plate I.)

The erection of a ten-head battery in 1895 at Nullagine, where the first crushing of 184 tons yielded 210ozs. 16dwts. of gold, appeared to have given a great impetus to mining, for the Warden of the field, writing in July of that year, reported:—"Quite a boom in leasing has commenced."*

The following year, the Inspector of Mines for the Northern Goldfields stated:—"At the Nullagine, quartz reefing (which has only been inaugurated during the past 18 months) is making rapid advances, crushings having yielded from 2ozs. to 8ozs. per ton, while the acquisition of a large area of conglomerate holdings by an English company marks a new era in the history of the district.†"

The progress of Nullagine during the year 1897 is thus alluded to by the Warden in his Annual Report to the Minister for Mines:—"Besides alluvial digging and quartz reefing, gold is obtained from conglomerate lodes with payable results. There is one ten-head battery, and two more are in course of erection. Water is obtained at an average depth of 50 feet. The yield of gold for the year is 982ozs. There are regular consignments of alluvial gold from Nullagine, of which I have no record; but, from information obtained from the business people, I should say that, at the lowest estimate, these would amount to 600ozs. per annum."‡

Writing on the advances made on the Pilbara Goldfield during 1898, the Warden thus alludes to the progress of Nullagine:—"The North-West Australian Goldfield, Ltd., at Nullagine, are showing their confidence in their conglomerate lodes by supplementing their crushing machinery and laying down tramways, and thus, by working on a large scale, endeavour to decrease expense and make their properties pay."§

No mention is made of the progress of Nullagine during 1899, 1900, and 1901 in the reports of the Warden, as published in the annual reports of the Mines Department; for 1902, however, it is

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* Supplementary Report on the Department of Mines, 1st October, 1895. Perth: By Authority, 1895, p. 4.

† Pilbara and West Pilbara Goldfields, 1896. S. J. Becher. Report of the Department of Mines for the Year 1896. Perth: By Authority, 1897, p. 36.

‡ Report of the Department of Mines for the Year 1897. Perth: By Authority, 1898, p. 23.

§ Report of the Department of Mines for the Year 1898. Perth: By Authority, 1899, p. 19.

stated :—" A large amount of good and useful development work is being done in the Nullagine District, where a further ten-head of stamps is being erected on the British Exploration and Development Company's property, which, when completed, will enable them to run 15 head, and for which purpose they are carrying out a water scheme which, when completed, will bring water a distance $1\frac{1}{4}$ miles from the river to the mine. Later on another 20 head is proposed to be erected."*

The year 1903 was a very quiet one in Nullagine n so far as any mining was concerned, and no mention is made of its progress in the Annual Departmental Report for that period.

General Geology.

The following represents in tabular form the geological formations in the district embraced by the area of the map. The stratified rocks are arranged in geological sequence :—

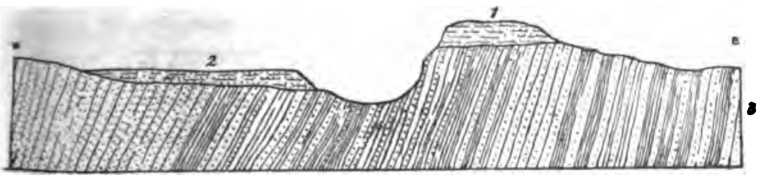
Alluvial deposits.
Laterite.
Nullagine series. Quartzites, grits, conglomerates and interbedded igneous rocks.
Unconformity.
Mosquito Creek beds.—Sandstones, fine conglomerates and shales.
Greenstone dykes.

Alluvial Deposits.

The banks of the Nullagine River and its tributaries are skirted by a variable width of alluvium, the full extent of which has been shown on the geological map. The greatest width attained by the alluvium is about 50 chains, but in no case does it reach any great thickness.

The south-eastern banks of the Nullagine River show a considerable extent of alluvium at a much greater elevation than that of the present water-courses. This is depicted in Fig. 1. This

Fig. 1.



SECTION ACROSS THE NULLAGINE RIVER NEAR TOWNSITE. PILBARA G.F.

1. Older alluvium. 2. Newer alluvium. 3. Sandstones, grits and shales.

section shows the remains of an older alluvium laid down at a time when the Nullagine River flowed at a slightly higher level than now.

*Report of the Department of Mines for the Year, 1902. Perth: By Authority, 1903, p. 44.

Writing in the year 1890, Mr. H. P. Woodward says, with reference to the alluvial deposits of Nullagine, that * :—

"Three classes occur; 1st, the alluvium of existing creeks; 2nd, the alluvium of older creek beds, but in conjunction with the present streams; 3rd, older alluvial deposits or deep leads bearing no relation to existing streams or configuration of the country. . . The older alluvial deposits are found in the river flats, where the auriferous gutters are crossed and recrossed by the present streams. The sinking here is about 10 feet, and very hard work, owing to the fact that the deposits that overlay the dirt are cemented masses of quartz and boulders of other hard rocks. . . . The deep leads are cut across by the present valleys, and can be traced from hill to hill. Here the sinking is very variable in depth, the whole gutter in some places appearing on the side of a cliff where the work merely consists in driving, while in other places shafts up to 60 feet or 70 feet have to be sunk to work the same lead. Up to the present only one of these leads has been discovered, but there cannot be the least doubt that more will be found when the small hills between the conglomerate range and the creek are thoroughly prospected. All three of these deposits are very rich, but no one can estimate the quantity of gold with any degree of accuracy, as so much leaves the colony without ever being reported; but there is no doubt that more has been taken from this field than from any other in the colony."

It is not quite clear from what can at present be seen in any of the sections exposed in the neighbourhood of Nullagine, that what are described above as "deep leads" are such; the impression left upon my mind is that they merely represent weathered outliers of the basal members of the Nullagine Series.

Table showing the Yield of the Alluvial and Superficial Deposits of the Nullagine District generally.

Year.	Gold.
	ozs.
1897	No data.
1898	1,000·00
1899	729·79
1900	27·00
1901	831·02
1902	390·67
1903	288·30
1904	403·24
Total	**3,670·02**

* Annual General Report of the Government Geologist for the Year 1890. Perth: By Authority, 1891, p. 25.

Laterite.

A very noticeable geological feature of the area, is the occurrence of several isolated tablelands of laterite; the area which these occupy has been accurately delineated upon the map of the district. One very important feature which the map, owing to the lack of contour lines, fails to bring out, is the uniform level at which this laterite invariably occurs.

The most conspicuous tableland is that which lies to the south-west of the township, and about a quarter of a mile west of the river bank. The tableland has a length of about a mile and a quarter, and an average width of about 10 chains; it presents a steep bluff, several feet in height, which extends with scarcely any interruption all round the plateau.

This tableland is breached by that tributary of the river which flows into it near Suburban Water Right No. 5. The laterite continues from this point as a narrow strip far beyond the limits of the map. Three other outliers occur to the north of Beaton's Creek, the most conspicuous being that which lies adjacent to the township of Nullagine.

An inspection of the geological map demonstrates that the laterite traverses successively all the geological formations, with the single exception of the modern alluvium.

In its lithological characters, the deposit presents all gradations from ferruginous claystone to pure limonite; the rock itself is very porous, and weathers readily into caverns and cavities of all sizes; in some places the surface of the rock is covered with a glaze of hydrated oxide of iron. When seen in section, it is noticed that the laterite passes by insensible gradations into the underlying strata without any sharp line of demarcation.

Mr. Woodward refers to what is evidently the laterite series as follows: "Another line of flat-topped hills, but lower, extends along the side of the creek, but these are of much more modern formation,* and it is in these that the deep leads are met with. The beds which form these hills rest directly upon the indurated slates,† and pipeclay, soft white sandstone, gypsum, and boulder beds. The wash is often very ferruginous and hard, necessitating crushing. The whole of these beds are capped by a ferruginous sandstone containing large quantities of fossil wood." ‡

It may be noted in this connection that I saw nothing which could be described as fossil wood anywhere in the series, as exposed in the vicinity of Nullagine, this, however, may possibly be due to the fact that at the time the district was visited, work was in full swing, and Mr. Woodward may have had better opportunities for observation than were open to me.

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* The beds of the Nullagine series.—A. G. M.
† The Mosquito Creek Beds.
‡ *Ibid.*, p. 35.

The Nullagine Series.

Sedimentary Rocks.

The Nullagine Series is largely developed in the Pilbara Goldfield, and consists of a great thickness of sandstones, grits, conglomerates, and limestones, some of which are magnesian, together with a series of lavas and ashes and agglomerates of as yet unascertained thickness.

The formation, the base of which is rarely seen, makes a prominent feature in the landscape of the district, and plays a very important part in the geology of the north-west, in addition to being of some economic value by reason of the basal members of the series having been proved to be auriferous in at least two localities many miles apart.

Previous reference to the Series.—In Bulletin 15 full descriptions have been given of the different sections which illustrate the relationship of the Nullagine Series to those beneath,* and therefore need not be repeated.

Mr. H. P. Woodward, in the year 1890, makes the first brief official mention of the auriferous conglomerate of Nullagine in the following terms:—"To the west of this field are hills of nearly horizontally-bedded conglomerate rocks, probably of Devonian Age, in which reef gold occurs in small veins of quartz and ironstone, which follow and indeed fill in all interstices between the larger boulders. They are very rich in places, in fact so rich that it pays to 'dolly,' and the gold in the flat close by is evidently derived from these veins. This deposit is of very great interest, as nothing like it has before been found, for the gold, although occurring in an alluvial deposit, is reef gold and not alluvial, for it has been deposited subsequently to the formation of these boulder beds."†

On a later page of the same report, in the description of the country traversed from Geraldton to Nullagine, Mr. Woodward gives a few particulars with reference to the auriferous conglomerate and its relation to the older strata in the following terms:—"In this conglomerate the gold is alluvial in character, but it is true reef gold, being deposited there subsequently to the deposition of the boulders between which it has been infilled with silica and iron, probably by thermal action. These beds dip at an angle of 12 degrees to the north-west. They vary greatly in character from quartzite to boulder conglomerate, but it is only in the ferruginous beds that the gold is found. This formation is probably of Devonian Age, resting unconformably upon the edges of the clay slates and quartzite conglomerate beds with quartz reefs of the metamorphic series." ‡

The latter portion of this description shows that the violent unconformability separating the beds of the Nullagine Series from those of the Mosquito Creek beds was at least recognised, though not emphasised, by Mr. Woodward fifteen years ago.

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* pp. 18, 20, 21, 22, 23, 24, 25, 27, 28, 30, and 31. † Annual Report of the Government Geologist for the Year 1890. Perth: By Authority, 1891, pp. 25-26. ‡ *Ibid.*, pp. 34-35.

Writing in the year 1895, the Acting Inspector of Mines, Mr. S. J. Becher, informed the Minister for Mines that:—"Nullagine, one of the oldest and best districts of the whole field (Pilbara Goldfield), lies about 80 miles south-east of Marble Bar. Geologically, it is perhaps unique. The general character of the country is that of table-topped hills about 200 feet high, intersected by deep ravines, gullies, and valleys, widening out into flats and plains in all directions. In the immediate neighbourhood of the township the main characteristic features are:—First and centrally, flat-topped hills having ironstone formations, as 'crust,' overlying decomposed conglomerate matter; secondly, hills more rounded on top consisting of red and white cement and conglomerate deposits of varying thickness, some of the waterworn quartz being quite boulders in size. The conglomerate contains a great quantity of ferruginous matter, and this apparently carries most of the gold, which occurs in a fine state."

"The central hills seem to have been the result of denudation and decomposition of the material of the surrounding conglomerate and other formations. For the past six or seven years, there has been a steady output of alluvial gold from this field. Every gully has been systematically worked, the wash being screened and then carted down to the pool in the river for puddling and washing. The screenings, etc., have even been reworked at a profit by dry-blowers. It was noticed that the 'runs' of gold extended up the hill sides from out of the creeks and gullies. These runs were followed up the surface rubble for a few inches in depth, being all put through the dry-blowing machines, until the run ceased, when it was found that the original source of the gold was a seam or perhaps a big lode of conglomerate, whose outcrop was on the contour line where the run of gold ceased extending up the hillside. Though alluvial work is still carried on, more attention is now paid to the conglomerate lodes, which are being extensively worked and put through the battery with payable results."

"Of late, too, some very rich reefs have been found a few miles out, in what is locally known as the 'claypan' country. Crushings from the outcrops and superficial works on these reefs are returning from 2 to 4 ozs. per ton, and their prospects of permanency in depth are, it is said, good."

"The conglomerate lodes have attracted the attention of English Capitalists, and there will soon be extensive works thereon in operation. . . . " *

In 1898, Mr. S. J. Becher describes the conglomerates of Nullagine in the following terms:—"In the immediate vicinity of Nullagine township or mining camp, range upon range of conglomerate hills lie to the north-west. . . . The course of the river . . . follows the outskirts of the conglomerate country, keeping on the farther side of the slate country and its

* Report of the Department of Mines for the Year 1895, Appendix 5. Perth: By Authority, 1896, p. 29.

quartz reefs, and forms a marked line of division, as it were, between the characteristic topographical features of the district. . . . Coming then to the conglomerate ranges, which average in height about 100 to 150 feet above the level of the river flat we find that the hills in the forefront, upon which the chief mine workings are at present situated, appear to be mostly round-backed and strewn with rounded boulders and pebbles. On closer examination, one finds that they consist of bed upon bed of conglomerate, merging into intermediate layers of kaolin. The beds dip universally to the north-west, and strike north-east and south-west. The dip is flat, averaging perhaps 15 degrees. Therefore as one approaches from the south-east the hill-sides exhibit longitudinal sections of the country, and in some cross gorges very complete studies may be made of cross-sections; whilst, where the rounded weathered hill sides slope to the flat, one may notice somewhat regular lines of round boulders and pebbles roughly marking the outcrops of the conglomerate beds. By these indications, and also by following up the runs of alluvial gold until they stopped all along certain horizontal lines, the auriferous conglomerates were originally located and worked by prospectors by means of drifts and tunnels."

"Some of the conglomerate beds contain boulders up to three or four feet in diameter, while others carry nothing bigger than a man's head. These boulders consist of rounded masses of fragments of quartz, trap rocks, and other conglomerates. A peculiar feature about the shape of these is that they are very often somewhat flattened like curling stones. This flattened shape might suggest glacial action, but the writer saw no striæ. These have, the writer understands, proved to be less auriferous than the other beds whose component particles are small. The best gold seems to be obtained from ferruginous veins. The ore now being crushed by the mining companies varies in value, the writer believes, from 10dwts. to 2ozs. per ton, the treatment being by battery and amalgamation alone. The gold is worth £3 17s. 6d. to £4 per ounce. At the time of the writer's visit, in the year 1896, only the decomposed portion of the beds had been worked, but he is given to understand that a vertical shaft has since cut a bed in depth below the zone of decomposition, and that the character of the rock is a very hard greenstone conglomerate, carrying much iron pyrites, samples of which have yielded returns by assay up to 13dwts. per ton."

"Behind these round-backed series of hills, to the westward, the topographical features vary again, and the conglomerate ranges assume an appearance of being terraced, the reason of which becomes evident upon examination. Following up into these ranges an affluent of what is known as the main creek, one enters a gorge with precipitous sides rising to 50 feet in height, and here a very fine cross section of the country may be examined. Here it may be seen that, interbedded conformably with the beds of conglom-

PHOTO.: S. J. BECHER.

Beaton's Pool, showing the Conglomerates and Interbedded Ashes, Nullagine.

erate, there are indurated slates and grits. The former, where long exposed to the action of the atmosphere and water, split off into flags."

"Compared with the above-mentioned series, little or no decomposition has taken place beyond surface-weathering, which accounts probably for the fact that no free gold (to speak of) has been obtained in the gullies, and that the terraced series is not at present recognised as auriferous. Time may prove this. The terracing is due to the unequal effect of weathering on the exposed longitudinal edges of these otherwise undecomposed beds of varying durability."

"As to the age and origin of these interesting Nullagine beds, nothing definite is yet known. . . . ." *

Professor David, writing in 1902 on the Permo-Carboniferous glaciation of Western Australia:—"There is . . . in my possession a photograph (Fig. 5) taken by the late Mr. Becher of the Geological Survey of Western Australia, of a remarkable conglomerate at Nullagine, Pilbara, Western Australia, which so closely resembles in general appearance the Cambrian glacial beds of South Australia as at once to suggest a possible glacial origin for the West Australian beds. They are also associated with a very finely-laminated shaly altered rock, not unlike the Tapley's Hill shales, which overlie the Cambrian (?) glacial beds of South Australia. These Nullagine beds are probably of older palæozoic age (? pre-Cambrian), and should well repay further investigation." †

The finely-banded rock, to which Professor David thus alludes, is probably either one of those lavas or ashes, which lie near the base of the series and are well exposed in Beaton's Creek, and the Nullagine River itself.

In the more immediate vicinity of Nullagine there are several cliff sections which show the mutual relationship of the various members of the series. (Photograph "A.")

In Beaton's Creek, a tributary of the Nullagine River, which it joins at the foot of McFie Street, is a very good section, showing the relation of the interbedded character of the volcanic rocks, forming the basal members of the series.

A portion of this section is shown in Fig. 2.

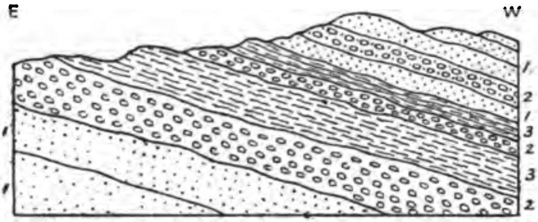
The cliffs near Beaton's Pool expose two beds of ash dipping to the westward at an angle of 17 degrees from the horizon. The uppermost bed attains a thickness of five feet six inches, and is separated by six feet of conglomerate from another ash bed 12 feet thick. In the geological map, owing to the smallness of the scale, this deposit has been treated as one bed. The mapping shows that the bed is merely an attenuated lenticular patch of no very great horizontal extent.

* The Nullagine District, Pilbara Goldfield, Western Australia. Trans. Inst. Min. Engineers (Newcastle-upon-Tyne), 1898. Vol. 16, Pt. 1, pp. 44-52.

† Report of the Glacial Committee. Austral. Assoc. for the Adv. Sci., Vol. 9, 1902, p. 201.

A little distance below the pool is another much thinner bed of somewhat greater horizontal extent; it can be followed northwards as far as the southern angle of G.M.L. 2L. (216) "The Trinity," where it is cut off by the fault which traverses this portion of the district. A good section of the ash is to be seen in the gully to the south of "The Trinity," at a considerable altitude above the level of Beaton's Pool, for the strata rise very rapidly in this direction.

FIG. 2.



SECTION AT BEATON'S POOL PILBARA G.F.
1 SANDSTONE. 2 CONGLOMERATE. 3 ASH.

The uppermost bed of ash [5796], which forms a fall over which the waters of the creek drop into Beaton's Pool, extends about 50 chains to the northward, where it also is truncated by the fault previously alluded to. In the vicinity of the fault, the bed has a slightly increased dip of 20 degrees to the west. A small attenuated portion of it is to be seen on the downthrow side of the fault near the head of one of the branches of Beaton's Creek. It is possibly this bed which occupies the topmost stratum of the synclinal trough occurring on M.L. 1L. There is however no great thickness of ash in this section, the bed evidently thinning out rapidly in this direction.

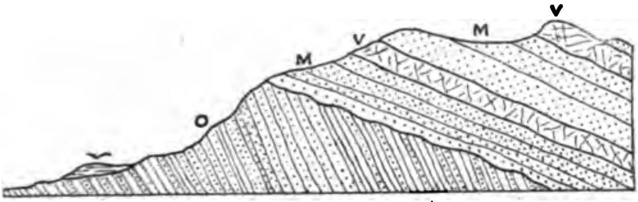
A traverse up Beaton's Creek for about a mile or so above the pool shows the beds overlying the ashes to consist of conglomerates [5797] and grits disposed in a series of gentle folds, with dips varying from 5 to 8 degrees from the horizontal. The cliffs rise to considerable elevations above either bank of the creek, and show good sections of the strata. The beds are traversed by a series of rectangular joints which have proved to be the dominant factor in determining the general direction of the watercourse.

An important section is to be seen on the southern bank of the Nullagine River at a point about 40 chains south-west of Suburban W.R. 5L, which discloses the violent unconformability separating the Nullagine from the underlying series (Fig. 3):—

The basal member of the Nullagine Beds in this section consists of a few feet of grit and conglomerate, overlaid by about 3 feet of ash, the whole dipping at an angle of about 18 degrees to the south-west. These rest upon the upturned edges of the quartzites and

dense shales forming the Mosquito Creek Beds, which latter dip at angles averaging about 70 degrees in a south-west direction.

FIG. 3.



SECTION OF THE NULLAGINE RIVER NEAR W.R. 5L PILBARA G.F.

— ALLUVIUM O QUARTZITES & DENSE SHALES (MOSQUITO CREEK BEDS)
V LAVAS & ASHES } (NULLAGINE BEDS.)
M CONGLOMERATES & GRITS.

Some distance higher up the river the conglomerates and grits of the Nullagine Beds are overlaid by acidic lava [5795]. These volcanic beds occupy the country as far as Wild Dog Camp, Res. 3328,* about 16 miles above the township, and entirely conceal the sedimentary rocks beneath. In the neighbourhood of Wild Dog, the lavas are somewhat amygdaloidal [5808]. In certain portions of the district, the irregularities of the old surface upon which the beds were laid down is such that the volcanic beds often overlap the older rocks.

About four and a-half miles eastward, the volcanic rocks rest directly upon granite, at an altitude of about 200 feet above the well at Wild Dog Camp, the sedimentary rocks beneath being absent. This granite country is traversed by several quartz reefs. A very prominent reef, having a general trend of 248 and 63 degrees with a horizontal extent of a few miles, does not appear to be a fissure vein, as generally understood, but merely a gradual replacement of the surrounding granite by silica along a main line of weakness.

The bedded lavas, which are sometimes vesicular, were followed westwards some miles beyond Trig. Station G 13, on the head waters of the Coongan River; and from their mode of occurrence in the field, it is evident that they rest in this locality upon a very uneven surface.

No opportunity presented itself of tracing the boundary of the Nullagine Series to the south of Wild Dog Camp, but so far as may be judged from Mr. Woodward's descriptions, the formation would appear to extend to a point a few miles to the westward of Bamboo Spring (Res. 1927) on the head waters of the Shaw River, for it is stated "the rocks (near Bamboo Spring) are quartzite and basalt, with veins of chalcedony and inferior opals; the chalcedonies are

* Lands Department Lithograph 16 G.

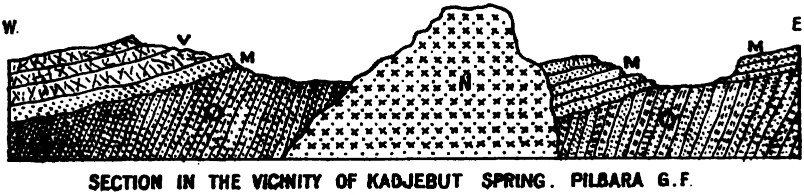
often finely banded, and should be of considerable commercial value, as they can be obtained in large blocks."*

From a personal knowledge of the country, I have very little doubt as to the identity of the strata to which Mr. Woodward refers with those already described.

The road from Nullagine to Wild Dog Spring passes, after getting clear of the town, near Kadjebut Spring, a watering place on the creek of that name. In the vicinity of the spring, there are several sections which give a fair idea of the relation existing between the various rock formations.

The Fig. 4 gives a generalised section of the country in the vicinity of what is known as the rock hole, near Kadjebut Spring.

FIG. 4.



SECTION IN THE VICINITY OF KADJEBUT SPRING. PILBARA G.F.

V. LAVA & ASHES } NULLAGINE SERIES
M. GRITS & CONGLOMERATE }
O. SANDSTONES, CONGLOMERATES & SHALES. MOSQUITO Cr. SERIES
N GABBRO.

On the western side of the large dyke, which at this point attains a considerable thickness, the Nullagine Series is represented practically by lavas and ashes, with a thin bed of conglomerate underlying. The beds rest with a violent unconformity upon the upturned edges of the Mosquito Creek Series. The Nullagine conglomerates and grits abut directly against the dyke along its eastern wall. So far as can be seen, there is no evidence of alteration of the sandstone and conglomerate anywhere along the line of contact between them and the dyke, nor so far as I could detect were there any pebbles of the gabbro contained in the conglomerate. The evidence so far as it goes seems to point to the junction between the two formations being in this locality a line of fault. In no place, however, did this dyke pierce the Nullagine conglomerates, though some miles northward in the vicinity of the One-mile Creek, a narrow dyke of a similar character does rise to the level of the Nullagine Series, and can be followed across country north-west and south-east traversing in turn each individual bed.

The basal conglomerate is made up of rounded, ellipsoidal, or subangular fragments of the strata forming the older underlying series (the Mosquito Creek Beds). These often include pieces which may reach a length of three or four feet, but the bands containing the larger fragments are merely local. Photograph "B"

* Loc. cit., p. 34.

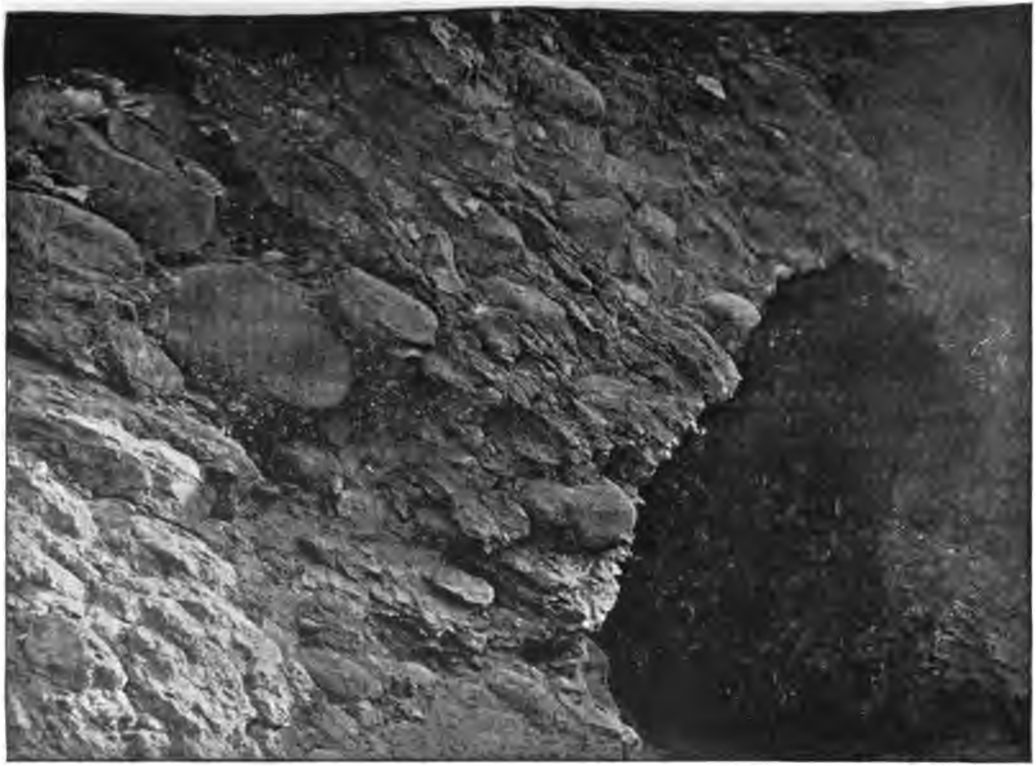


PHOTO.: S. J. BECHER

A portion of the Auriferous Conglomerate, Nullagine.

shows a portion of this conglomerate at the entrance to one of the mine workings. The conglomerate consists chiefly of fragments of the existing conglomerates, cherts, grits, and shales; reef quartz, identical in character with that forming the auriferous deposits in the underlying strata, being a very common constituent. The pebbles are embedded in a matrix, which is principally sandy, though sometimes aluminous.

Some portions of the conglomerate contain flattened and striated pebbles [5805] of fine-grained sandstone and sandy shales, identical in character with the beds of the Mosquito Creek Series; to these striated pebbles a glacial origin has been assigned by the late Mr. S. J. Becher, and subsequently by Professor David. These pebbles, however, would, in the light of the evidence now available, seem to have had their striation induced previous to their taking part in the formation of the Nullagine Series. The beds upon which the series rest with a violent unconformability and to the denudation of which the pebbles owe their origin, having been subject to intense mechanical deformation, it would only be natural to find slickensided fragments and pebbles in the newer rocks. Earth movements have caused the Nullagine Beds to be thrown into a series of undulatory folds, well shown in the geological map and section, but the deformation thus engendered has not been of sufficient intensity to cause any striation of the component pebbles.

The conglomerates or consolidated shingles are of distinctly sedimentary origin, and owe their occurrence to the disintegration of pre-existing strata, which will be fully described on a later page. From the angularity of many of the pebbles, which make up the mass of the basal members of the series, it may be reasonably inferred, that the coast-line which furnished them was not far distant. No outliers of the series occur anywhere in the vicinity of the country embraced by the Geological Map of Nullagine. From this fact and the angularity of many of the conglomerate pebbles it may be inferred that the present boundary of the series approximately marks the original shore-line. The evidence available from a careful study of the district over which the series extends, shows that the surface upon which the beds were laid down was extremely irregular. This irregularity was particularly apparent in the neighbourhood in which the basal shingles have been mined. The auriferous strata occur through a thickness of about 300 feet of grits, sandstones, and conglomerate, forming the lowest portion of the series: those portions of the strata which have been proved to be gold-bearing are those which are largely impregnated with the oxides or sulphides of iron, and which lie between the fault north of Beaton's Creek and the greenstone dyke (possibly along a fault-line also) crossing the One-mile Creek in the vicinity of Mineral Lease 5L. As may be seen by the table below, the gold contents of the conglomerates are small, not amounting to more than at the rate of ·62 ozs. for the total tonnage crushed since mining first commenced.

Table showing the Yield of the Auriferous Conglomerates of the Nullagine Series.

Year.	Ore crushed.	Gold therefrom.	Rate per ton.
	tons.	ozs.	ozs.
Previous to 1897	357·60	434·70	1·21
1897	246·00	228·00	·92
1898	893·00	1,001·20	1·12
1899	753·40	533·35	·70
1900	382·00	149·90	·31
1901	1,458·00	647·53	·44
1902	300·00	128·51	·42
1903	777·00	94·10	·12
1904	*Nil*	*Nil*	...
Total	**5,167·00**	**3,217·29**	**·62**

Igneous Rocks associated with the Series.

From the geological maps and the descriptions given in this and Bulletin 15, it will be seen that a great series of bedded lavas, ashes, and agglomerates form an integral, and no small, portion of the series as developed in different portions of Pilbara Goldfield.

Wherever these beds have been examined it has been invariably found that they consist of acidic lavas, the composition of some of these [**5392**, **5404**, **5384**] which may be regarded as typical of the series have already been published in Bulletin 15 and need not be repeated.

The greater mass of the rocks consist of separate lava-flows, each of no very great thickness. Some of the lavas are distinctly amygdaloidal, the cavities being filled with chalcedony.

Some of the finer-grained ashy beds [**5796**] differ very little in general appearance from many of the banded lavas, with which they are associated, but their distinctly fragmental character can readily be made out by the microscope, and in some cases with the aid of a pocket lens.

So far no evidence has been obtained which would throw any light upon the sources from which the lavas emanated.

In the neighbourhood of Coppin's Gap, the volcanic rocks of the Nullagine Beds are represented by coarse agglomerate, dipping at angles of about 20 to 30 degrees to the east, and passing beneath the sedimentary rocks of the series. Associated with these are beds of greenish grey lava. The sedimentary rocks of the series which occur at a somewhat higher horizon consist of coarse conglomerate and fine-grained sandstone. The hills of conglomerate rise to considerable heights above the surrounding plains, which in this particular locality are underlaid by granitic gneiss and allied rocks.

On the Coongan River, some distance below the township of Marble Bar, a mass of volcanic agglomerate forms a very conspicuous irregular-shaped hill, which presented every appearance of being the focus from which the surrounding lavas emanated.

There are several acidic dykes visible in different portions of the district, which may possibly represent another phase of that volcanic activity which was rife.

In the neighbourhood of the townsite of Nullagine, a mass of quartz felsite [5798] was met with in the well on W.R. 2L. This well has been carried down to a vertical depth of 108 feet, through quartz felsite the whole way. This rock, the position of which is shown on the map of the Nullagine Conglomerates Gold Mines forming Plate II., makes its appearance on the western bank of the creek, and rises to about the level of the floor of the battery site, where it seems to have diffused itself through a portion of the coarse auriferous conglomerate forming the base of the formation in this locality. The quartz felsite is very much decomposed, the alteration extending as far down as the bottom of the well, which is the deepest point at which it has been pierced. Examined under the microscope, the rock is found to consist of quartz and plagioclase, set in a partially devitrified matrix.

Age.

The recognition of the position of the Nullagine Beds in the stratigraphical succession is a point of considerable importance; the absence of fossils throughout the series, wherever it has yet been studied, however, renders correlation extremely difficult.

The earliest investigator of the district, Mr. H. P. Woodward,* assigned a Devonian Age to the series, though the evidence does not seem to be conclusive. The next observer, Mr. S. J. Becher, writes that of "the age and origin of these interesting Nullagine Beds nothing definite is known." †

Professor David infers that the beds are "probably of older Palæozoic Age (? pre-Cambrian) and should well repay further investigation." ‡

The limestones of the series having yielded no fossils, petrographical resemblance seems to be the only method by which any clue can, in the present state of our knowledge of the series, be arrived at with respect to its age.

In a previous report § the difficulty of correlating the Nullagine Beds with any of the formations described in the official publications on the geology of Western Australia was fully set out, and

* Annual Report of the Government Geologist for the Year 1890. Perth: By Authority, 1891, pp. 25 and 26.

† The Nullagine District, Pilbara Goldfield, Western Australia. Trans. Inst. Mining Engineers (Newcastle-on-Tyne), 1898. Vol. 16, Pt. I, pp. 44-52.

‡ Report of the Glacial Committee. Austral. Assoc. for the Adv. Sci. Vol. 9, 1902, p. 201.

§ A. Gibb Maitland. Preliminary Report on the Geological Features and Mineral Resources of the Pilbara Goldfields. Bull. No. 15. Perth: By Authority, 1904, p. 10.

the lithological resemblance to the quartzites, etc., of the King Leopold Range, in Kimberley, was emphasised. If this petrographical resemblance should prove to possess greater significance than at present appears, the Cambrian Age of the Nullagine Series would seem to have strong claims for consideration.

The Nullagine Beds have a very wide distribution in the North-West Division, and the Volcanic Series would seem to occupy a large area of country in the southern portion of the district. It may be noted that, in a bore put down by the Government at Onslow, near the mouth of the Ashburton River, to a depth of 1,729 feet, there was passed through a thin bed of a volcanic rock ("basalt" of the bore journal) identical in its characters with some of those igneous rocks forming part of the Nullagine Beds as developed elsewhere. It may thus be that these strata were pierced in the lower portion of the Onslow bore-hole.

Undoubted Permo-Carboniferous fossiliferous rocks are known to occupy a large area of country in the watersheds of the Gascoyne, the Minilya, and the Lyndon Rivers; hence an examination of the (geologically unknown) country lying between Onslow and the Lyndon River should afford some valuable information as to the mutual relations of the Permo-Carboniferous and the Nullagine Beds; hence it is from this district that the most important clue to the age of the Nullagine Series may be ultimately hoped for.

Mosquito Creek Beds.

The Mosquito Creek Beds, which underlie the strata of the Nullagine Series, comprise one of the oldest of the sedimentary formations as developed in Pilbara. The formation is abundantly represented, and occupies the surface of a very large area of country. The series, which consists of grits, shales, and fine conglomerates, takes its name from the district of Mosquito Creek, 24 miles due east of Nullagine, where these beds were first noticed.*

In that report attention was directed to the difficulty of separating the schistose rocks, which make up a large portion of the district, from these sedimentary rocks, and further observations have only served to emphasise that difficulty. As will be noted in the description of the geology of the Warrawoona field, which is made up of a mass of sedimentary strata, and associated igneous rocks, converted into crystalline schists, by metamorphic agencies operating on a regional scale, there seems good reason to believe that in the Mosquito Creek district the same conditions prevail.

The old 40-mile road from Mosquito Creek to Sandy and Middle Creeks follows an open longitudinal valley occupying the summit of a very broad anticlinal fold, which forms a very important structural feature in the district. It is upon the northern

* Preliminary Report on the Geological Features and Mineral Resources of the Pilbara Goldfield. A. Gibb Maitland. Bull. 15, Perth: By Authority, 1904, p. 78.

and southern flanks of this arch that all the auriferous quartz reefs of the Nullagine-Mosquito and Middle Creek zones occur.

A traverse from Nullagine township, south-eastward for about six miles to the cairn G. 16, on the summit of South Dromedary,* discloses a succession of highly inclined grits, sandstones, and shales with quartz veins. The whole series which forms the low ground underlies to the westward.

The two hills, the North and South Dromedary, which form the most conspicuous features in the landscape, rising as they do to a considerable elevation above the general level of the surrounding country, expose what appears to be the base of the Mosquito Creek Series.

The South Dromedary forms a ridge which has a general trend of north 50 degrees east, and a length of about half-a-mile. It is made up of vertical beds of conglomerate of considerable thickness. The conglomerate is very much cleaved, and the cleavage planes are seen to cut clean through the centre of many of the quartz and other pebbles. It may be noticed that the conglomerate contains numerous pebbles of laminated quartzite (chert), belts of which form such a conspicuous feature in other portions of the district, and are described in the previous report (Bulletin 15).

About two miles and a-half to the south-east of Quartz Claim 32* is a cairn, forming the summit of a tortuous ridge of laminated quartzite (chert). This quartzite underlies at an angle of about 40 degrees to the west, and with an average strike of north 70 degrees east. A few feet to the west of this is a remarkably conspicuous vein of quartz of considerable horizontal extent. From the position of this laminated quartzite, it would appear as though the beds in which it is enclosed belong to an older formation than that which comprises the strata of the North and South Dromedaries.

Between this hill and the South Dromedary (G. 16), sandy and micaceous beds (? sandstones or grits) of the Mosquito Creek type prevail. These strata are traversed by numerous quartz veins, lying parallel to the planes of bedding (? cleavage).

Farther to the eastward, a normal granite makes its appearance. This granite, which is clearly intrusive into the strata just described, is traversed by pegmatite veins which have, when viewed on the whole, a general strike of north 80 degrees east. In addition to the pegmatite veins, the granite is also seamed with an approximately parallel series of quartz reefs, which may merely represent another phase of the pegmatitic intrusions.

No estimate in the present condition of our knowledge of even the approximate thickness of the Mosquito Creek Series can be made, though the apparent enormous thickness of the formation may, in all probability, be due to the repetition of the beds by folding.

* *Vide* Mines Department Lithograph, L 76.

No trace of fossils having been met with anywhere in the series, so far as it has been examined, any definite data as to the age of Mosquito Creek beds is unavailable.

Observations, fully set out on an earlier page, demonstrate that they lie unconformably beneath the Nullagine Beds, and as in certain portions of the district the Mosquito Creek Series have been subjected to more or less intense dynamic metamorphism, a considerable period must have elapsed between the deposition of the two series.

The Mosquito Creek Beds are of economic importance, by reason of the fact that they form the matrices of the numerous auriferous quartz reefs which outcrop along a belt of about 24 miles in length, and have been more or less perfunctorily worked. A full description of the reefs occurring in the Mosquito, Sandy, and Middle Creek districts has already been given in Bulletin No. 15, pp. 78-101, and need not be repeated. In this report, particulars will only be given (under the heading of Economic Geology) of those reefs, etc., embraced within the area covered by the Geological Map of Nullagine (Plate I.), and to which no previous reference has been made.

As may be seen by a reference to the table below, the gold contents of the reefs are high, having an average of nearly 3ozs. for every ton of stone mined and milled, though the actual quantity of ore raised has, up to the present time, been very small.

Table showing the Yield of the Auriferous Quartz Reefs of the Mosquito Creek Series.

Year.	Ore crushed.	Gold therefrom.	Rate per ton.
	tons.	ozs.	ozs.
Previous to 1897	339·50	1,126·20	3·31
1897	151·00	450·95	2·98
1898	605·50	1,174·55	1·94
1899	12·70	79·60	6·27
1900	101·00	478·90	4·74
1901	28·25	187·10	6·62
1902	*Nil*	*Nil*	...
1903	*Nil*	*Nil*	...
1904	*Nil*	*Nil*	...
Total	1,237·95	3,497·30	2·82

Greenstone Dykes.

Apart from the igneous rocks which form an integral portion of the Nullagine Series, the greenstone dykes make a conspicuous feature of the country in the more immediate vicinity of Nullagine.

Lying to the west of the township of Nullagine, and distant about two miles, is a very prominent greenstone [5799] dyke, which

attains its greatest development along the eastern bank of Kadjebut Creek. The summit of this dyke is formed of a very rocky ridge, made up of large rounded and subangular blocks of greenstone, producing in places a surface of indescribable roughness. This dyke has a general north-east and south-west strike, and extends some miles in a northerly direction far beyond the limits embraced by the Geological map. It has a width of about 1,500 feet, and wherever seen in section the dyke has a decided tendency towards verticality. So far as could be seen, there appeared to be very little, if any, appreciable alteration of the enclosing rocks on either wall of the dyke. In two places along its course the dyke sends out tongues into the surrounding rocks. It is quite possible that there may be some underground connection between the main dyke and those two smaller ones which occupy a portion of the surface to the east of the Great Eastern line of reef. These two dykes, the position of which is shown on the Geological map, have a horizontal extent of about 15 and 50 chains respectively.

This large, or what may be called main, dyke is nowhere seen to pierce any other strata than those of the Mosquito Creek Series.

At a point about 20 to 30 chains to the west of this larger dyke is another approximately parallel one, first making its appearance between the Victory and the Day Dawn groups of leases, and traversing the country to the northward in the vicinity of M.A. 4 L until it disappears beneath the alluvium of the Nullagine River. Although it rises to a considerable height above the general level of the surrounding plain and forms a prominent surface feature, it nowhere exceeds a width of two chains. This dyke also does not pierce any other strata than those belonging to the Mosquito Creek Series.

On the north side of the Nullagine River, and in the vicinity of the One-mile Creek, is another greenstone [**5794**] dyke, trending generally north-west and south-east. It has been followed across country for a mile and a-half, and extends far beyond the limits of the map. This dyke, which traverses both the Mosquito Creek and the Nullagine series, does not make any very pronounced feature in the landscape, though it can be readily followed. Its width nowhere exceeds two chains in width, and when seen in section is vertical, or nearly so.

There seems very good reason for believing that this dyke may be the prolongation of that disappearing beneath the alluvium of the Nullagine River, in the vicinity of M.A. 4L. The course of the dyke north of the One-mile Creek is approximately parallel to that fault which lies to the north of Beaton's Creek, and it is quite conceivable that the One-mile Creek dyke may occur along a line of fracture also, although no obvious dislocation of the strata is apparent. Whatever may be the exact age of these dykes it is quite clear that the one last described is newer than the series of strata it penetrates.

The rock [5799] of which this dyke is formed is of medium grained, crystalline structure. The only minerals which are readily recognisable with the aid of a lens are felspar, pyroxene, and occasionally an iron ore.

Under the microscope, relatively large proportions of crystals of augite, some of which are changed into a pale green dichroic mineral, stand out very prominently. All the felspars, which seem to be plagioclase, and make up the greater part by volume of the rock, present in all cases that turbid, mealy aspect due to alteration. The iron ore seems to be either magnetite or ilmenite, though pyrites is present in some portions.

The rock [5794] forming the largest and most conspicuous dyke in the field is a very fresh, fairly cross-grained rock, consisting of pyroxene, with a metalloid lustre, together with a white, and in some cases, almost colourless felspar, plagioclase. The felspar forms by far the larger proportion of the rock, and, when examined under the microscope, is found to be very much altered. A little quartz can be detected in some portions of the slide. The specific gravity of the rock is 2·82.

An analysis of a fresh, unweathered specimen [5794] made in the Survey Laboratory, showed its chemical composition to be —

Silica, SiO_2	54·92
Alumina, Al_2O_3	14·27
Ferric Oxide, Fe_2O_3	1·28
Ferrous Oxide, FeO	5·25
Magnesia, MgO	10·32
Lime, CaO	6·42
Soda, Na_2O	2·50
Potash, K_2O	·64
Combined Water, H_2O	2·96
Hygroscopic Water, H_2O	·12
Carbonic Anhydride, CO_2	·38
Titanic Oxide, TiO_2	·90
Iron, Fe } FeS_2	·10
Sulphur, S }	·12
Maganese Protoxide, MnO...	trace.
	100·18

This apparently differs but little from that last described [5799], except in the coarseness of grain.

So far as any observations have at present been carried in the district, these dykes appear to have no apparent connection with any visible deep-seated rock of similar composition.

Economic Geology.

The Nullagine District comprises three distinct types of auriferous deposits, viz.:—Alluvial and other Superficial Deposits; Quartz Reefs; and Auriferous Conglomerates. The respective yields of each is shown in the table below.

Synoptical Table showing the Total Gold Production of Nullagine up to the end of 1904.

Nature of Deposit.	Ore crushed.	Gold therefrom.	Rate per ton.
	tons.	ozs.	ozs.
Alluvium and Superficial	...	3,670·02	...
Quartz Reefs	1,237·95	3,497·30	2·82
Auriferous Conglomerates	5,167·00	3,217·29	·62
Total	**6,404·95**	***6,714·59**	**1·04**

* This total does not include that of the alluvial gold.

From this table it will be noted that, in so far as the number of ounces is concerned, the alluvial and superficial deposits have proved to be the most important, whilst the yield from the quartz reefs has exceeded that from the auriferous conglomerates by 108·84 ounces, although the average grade of the quartz proves to be more than four times greater.

Considering the number of years this mining centre has been in existence, it must be candidly admitted that the gold yield is disappointing.

In addition to the above totals, 1,638·50oz. of gold have been obtain from the cyaniding of nearly 3,000 tons of tailings. It is, however, not possible to separate the yield of the tailings from each centre, but as they were all cyanided at Lambert's Treatment Works, M.A. 4L, it is probable that most of the ore was obtained from the more immediate vicinity of Nullagine itself.

Table showing the Yield of the Tailings Cyanided at Lambert's Treatment Works, M.A. 4L.

Year.	Tons treated.	Gold therefrom.	Rate per ton.
	tons	ozs.	ozs.
1902	1,960·00	1,259·05	·64
1903	840·00	379·45	·45
Total	**2,800·00**	**1,638·50**	**·58**

This return thus brings the total gold yield of Nullagine up to 12,023·11ozs., as recorded at the close of 1904.

Alluvium and Superficial Deposits.

The alluvium and the other superficial deposits call for no special notice, beyond the fact that there seems good reason to believe that no small portion of the "alluvial" gold was obtained from the numerous creeks draining that portion of the escarpment of the Nullagine Series lying between Beaton's and the One-mile

Creeks. Over this area, which is that occupied by the ferruginous basal conglomerates, skilful dryblowers are still able to obtain a certain quantity of gold, derived, in all probability from the residual concentration of the gold set free from the conglomerate. Owing to the circumstance that a considerable proportion of the gold so obtained is probably never officially reported, the actual yield from this source cannot be set out in figures.

Quartz Reefs.

Quartz reefs occur in great abundance in the country lying to the westward of the Nullagine River. These reefs outcrop over a belt about four miles in length, which emerges from beneath the beds of the Nullagine Series near Suburban Water Right 5L, and extends in a general north-easterly direction across the whole area of the geological map. So far as any observations have been made it seems that the productive area of the Mosquito Creek Beds, as developed in the more immediate vicinity of Nullagine, consists of a broad belt about a mile in width, with a general strike of north-east and south-west, which latter coincides with the general trend of the series.

The position of most of the quartz reefs has been accurately laid down upon the Geological Sketch Map of Nullagine (Plate I.). They exhibit, when viewed on the whole, a general parallelism, which is coincident with the plane of bedding of the enclosing rocks. The reefs invariably occur along the bedding planes, or, at any rate, cut them at a very low angle. Few of them attain any very great horizontal extent, nor, so far as could be judged by a careful inspection of the surface, did they reach, as a whole, any great thickness.

The quartz of which the reefs of Nullagine are composed is generally of a whitish colour, contains little, if any, pyrites, and of such a character as render it readily amenable to battery amalgamation and cyanidation.

Several of the reefs have been opened up and worked to relatively shallow depths.

The Mines.

No work of any description was being carried on at the date of my visit to the district, and none of the mines were accessible.

I have extracted a good deal of information from the manuscript reports of the different Inspectors of Mines, and the following notes may serve the purpose of giving some idea of the state of development of the mines and other cognate points at the time these officers visited the district. These notes, however, make no pretensions to being more than a mere general account It is much to be regretted that no better official record has been kept of the statement of development of the district, a condition of affairs which virtually obtains over the whole of such portions of the Pilbara Field as have yet been visited.

For convenience of description the various properties are dealt with in geographical order, commencing at the north-easternmost end of the field. The location of each of the properties described will be found on the Geological Sketch Map of Nullagine. (Plate I.)

Fisher's Reward, G.M.L. 65L.—This, the most northerly of the leases in the country to the east of the Nullagine River, is traversed by two small parallel quartz reefs of no very great horizontal extent. A very little desultory work has been done upon the property, which was held for a period of about four months during a portion of the years 1896 and 1897. A few tons of quartz were raised and crushed in 1897; the official figures show that 20 tons of ore crushed yielded 56·6 ounces of gold, or at the average rate of 2·83ozs. per ton.

Try Again, 66L.—This lease adjoins that last described, on the south, and was at one period of its history known as the Turkey Mary. There are two distinct vertical reefs on the property, the easternmost having the greatest horizontal extent. The lease appears to have been held for a period of about five months only, during a portion of the years 1896 and 1897. Two small shafts have been sunk, but although the reef proved to be small, it is stated to have been rich. There are no crushings recorded from the property.

Promise, G.M.L. 331 (25L).—This six-acre lease lies some little distance to the west of the Try Again and about 35 chains to the east of the Nullagine River.

The property appears to have been held for about 18 months, having been surrendered in July, 1897.

There are two short reefs outcropping near the north-western boundary of the property, and three others, the position of which is shown on the plan, adjoining. A vertical shaft, 20 feet in depth, was put down, but the Inspector of Mines' report states that there was no reef exposed in it. A second shaft, 25 feet vertical, was continued on the underlay for 25 feet farther, in a south-easterly direction, on a small quartz vein; this, in the eastern shaft, the Inspector of Mines' report states, attained a thickness of two feet. There appears to be no record of any crushings from this property in the official statistics, unless such are included with those from sundry claims. The field note book, however, of the late Mr. S. J. Becher, at one time Inspector of Mines, contains the statement that "about 30 tons crushed over 90ozs., and that the first five tons went 10ozs. per ton." From this it would seem that some very rich ore must have been met with.

Sunrise, G.M.L. 58L (480).—This lease is situated in the triangular piece of ground, bounded by the Nullagine River, Kadjebut Creek, and the gabbro dyke, shown on the geological map. A fairly well-marked quartz vein outcrops for some distance along the eastern boundary of the lease; and has been opened out by means

of a shallow shaft. Little or nothing, however, can be seen at the present time. The lease was abandoned in 1897; there are no crushings from the lease in the official statistics, unless any such are included under the heading of the yield from sundry claims.

SUNRISE No. 1, G.M.L. 57L (429).—This property, which adjoins the Sunrise on the north-east, appears to have been taken up in September, 1896, and abandoned in the month of January of the following year. A small quartz reef, probably a continuation of the Sunrise, occupies a portion of the surface, near the south-eastern boundary of the property. The only work done on the property appears to have been raising the few tons of quartz which are shown in the official returns. These demonstrate that, previous to 1897, 28 tons of ore crushed yielded 14ozs. of gold, or at the rate of ·50ozs. per ton.

THE GREAT EASTERN GROUP of leases lie about a mile to the south of the Sunrise, and are situated on the eastern bank of Kadjebut Creek, almost due west of the Nullagine township.

GREAT EASTERN, G.M.L. 59L.—The Great Eastern Reef makes a very pronounced outcrop, forming as it does the highest point of a low, though conspicuous ridge, which rises some 15 or 20 feet above the level of the surrounding country. The general strike of the reef is north-easterly, and, as measured at the surface, has an underlie of 70 degrees to the south-west; from this it would seem that the reef is much steeper at the surface than underground. The country rock of both walls of the reef is slate; the reef measures about four feet in thickness, and the quartz is white, with ferruginous portions, due to the oxidation of pyrites. A fair quantity of stone from the outcrop had been raised to a depth of from 15 to 20 feet from the ground level. Mr. Inspector Gladstone's report mentions a vertical shaft 40 feet in depth, which had been continued on the underlay for a distance of 80 feet. At 30 feet in the shaft, a level is referred to 35 and 40 feet in length, driven respectively north-east and south-west, whilst at 90 feet a north-easterly level had been driven for a horizontal distance of 40 feet. There is no information in Mr. Gladstone's report as to the dimensions or character of the reef in the mine, and the workings were inaccessible to me.

The following figures give the yield of the reef in so far as it may be gained from official data:—

Table showing the Yield of the Great Eastern Reef.

Year.	Ore crushed.	Gold therefrom.	Rate per ton.
	tons.	ozs.	ozs.
Previous to 1897	20·00	33·80	1·69
1898	150·00	168·95	1·12
Total	**170·00**	**202·75**	1·19

Enterprise, G.M.L. 76L.—This is an isolated lease about three-quarters of a mile to the north-west of the Great Eastern Group. It embraces a part of the old Union Jack Lease 40L. A fairly well-defined reef, which can be followed more or less interruptedly across the surface to the south-west for a distance of 2,500 feet, traverses the lease. Several shafts have been sunk to depths of which there is no information. Water is said to have been met with in two of them at 35 feet. These shafts have been utilised as a source of water for the Battery and Cyanide Plant at one time erected on M.A. 4L, which embraces part of the lease. There have been no crushings recorded from the property, unless they are included in the yield from sundry claims.

In the vicinity of this lease there are several other parallel reefs of smaller size, upon which a little work has been done at one time or another, but there are no particulars available in respect to the yield of any of them.

About 800 feet to the south-west of the Enterprise Reef is another parallel vein, which can be followed more or less interruptedly across the surface for about 3,000 feet, and it is quite possible that the reef, disappearing beneath the alluvial flat of the Nullagine River to the north-west of the Day Dawn Group, may represent an extension of it.

Scottish Chief, G.M.L. 64L.—This is an old abandoned twelve-acre lease, adjacent to the Day Dawn Group on the north. There are three well-defined though small reefs traversing the property, and upon two of them, the north and south reefs, shafts have been sunk; these, however, are inaccessible, hence no particulars are available. There do not appear to have been any crushings recorded from the property.

Day Dawn, G.M.L. 278 (17L).—Upon this property there are several well-defined parallel reefs outcropping. The reefs have an average strike of north-east, with an underlie of about 40 degrees to the south-east. The main reef, viz., that upon which the bulk of the work has been carried out, averaged on the surface about two feet in thickness. It consisted of a white, and, in places, very ferruginous quartz, and is stated by Mr. Inspector Becher to have contained very coarse gold. Mr. Becher notes that the reef had been opened by means of an underlay shaft 45 feet in depth, which was also connected with the surface by a vertical shaft of 20 feet. A little driving had been done along the reef to the south-east. At a later date, 1898, Mr. Inspector Gladstone notes that the shaft had been carried down to a depth of 69 feet, and that driving to 252 feet had been carried out. No particulars as to the nature of the reef underground is to be found in the reports of the inspectors, which is much to be regretted, as the workings are at the present time inaccessible. Only 266 tons of stone have been crushed during the three and a-half years the lease was in existence, particulars of which are shown in the table below. In addition to these figures, Mr. Becher notes that 18 tons of *débris*, with which the surface of the lease was covered, yielded 18oz. of gold.

Table showing the Yield of the Day Dawn Reef.

Year.	Ore crushed.	Gold therefrom.	Rate per ton.
	tons.	ozs.	ozs.
Previous to 1897	174·00	600·00	3·45
1898	92·00	102·70	1·11
Total	**266·00**	**702·70**	**2·64**

Day Dawn No. 1 South, G.M.L. 388 (43L).—A twelve-acre lease, adjoining that previously described, which was held for a little over twelve months and abandoned in December, 1897. Two short reefs, one of which may represent the extension of the Day Dawn, occupy a portion of the south-western corner of the ground. Very little work appears to have been done upon the property, and there is no record of any crushings from it.

Day Dawn North, G.M.L. 418 (52L).—No work of any moment appears to have been done upon this lease.

The Victory Group of leases, only one of which, however, is now extant, occupies an extent of country about a mile in length, over which several small quartz veins outcrop.

Victory, G.M.L. 134L.—This lease embraces the greater portion of what was originally the Victory East Extended, G.M.L. 56L (424 or 99L), Walter's Folly; the original Victory, G.M.L. 383 (42L), to which it is desirable the name should be still applied, is situated some little distance southwards along the line. Five shafts have been sunk upon the lease, and, judging by the condition of the dumps, a good deal of work must have been done. None of the shafts, however, were accessible to me, and there appear to have been no plans of the workings. Mr. Inspector Gladstone mentions two underlay shafts, each 135 feet deep, and connected with drives from which 172 tons of ore had been crushed for a return of 625ozs. of gold, and a main shaft, which at the date of his visit had been carried down 70 feet. According to the official records of the mine, given in the table below, the gold yield seems to have been high.

Table showing the Yield of the Victory (East Extended) Reef.

Year.	Ore crushed.	Gold therefrom.	Rate per ton.
	tons.	ozs.	ozs.
Previous to 1897	12·50	50·90	4·07
1897	42·00	195·25	4·65
1898	116·00	388·30	3·34
1899	*Nil*	*Nil*	...
1900	89·00	414·35	4·65
1901	25·50	181·00	7·09
Total	**285·00**	**1,229·80**	**4·31**

VICTORY NO. 1 EAST, G.M.L. 53L (419).—Known later as the New Victory Extended, G.M.L. 70. The reef, traversing the adjoining property previously described, extends more or less interruptedly along the south-eastern boundary of the lease. It has been opened up by an inaccessible vertical shaft, of a depth of which there appears to be no record. There are no returns of any crushings from this lease.

VICTORY, G.M.L. 383 (42L).—What is known as the main Victory reef traverses the south-eastern boundary of the property, though it makes very little show on the surface. An inaccessible underlay shaft had been carried down, according to Mr. Becher's notes, to a depth of 81 feet, on a quartz reef underlying at an angle of 60 degrees, and attaining a thickness of from three to four feet. The walls of the reef, as described by Mr. Becher, are "perfect," and are made up of a soft, fine-grained, solid, white sandy shale, which is stated to harden on exposure. The quartz is very highly coloured by oxide of iron, and, according to Mr. Becher, showed gold freely at the bottom. A vertical shaft was being put down at a spot 50 feet distant from the mouth of the underlie shaft, designed to intersect the main reef at about 80 or 90 feet, but there is no official record as to whether this was accomplished. At the time Mr. Becher was at work in the Nullagine district, a small crushing of 25 tons of stone from the reef in the inclined shaft is reported to have yielded 130ozs. of gold, or at the rate of 5·20ozs. per ton of ore crushed. A small trial crushing of a few tons by former holders of the property yielded gold at the rate of 3ozs. per ton. The official yield of this lease is given in the table below.

Table showing the Yield of the Victory Reef.

Year.	Ore crushed.	Gold therefrom.	Rate per ton.
	tons.	ozs.	ozs.
Previous to 1897	75·00	337·50	4·50
1897	46·00	83·60	1·81
Total	**121·00**	**421·10**	**3·48**

VICTORY EXTENDED, G.M.L. 51L (417).—A small six-acre lease adjoining G.M.L. 383 on the south-east, and traversed by a reef which was thought to be the southern extension of the Victory. So far as can be judged, however, it seems probable that it is a parallel reef. An underlie shaft had been carried down on the reef to a depth of 30 feet, when it cut out. The shaft, however, was carried down another 20 feet, at which point a crosscut had been put in 20 feet to the north, with the object of testing the country, and another crosscut to the south had been commenced at the date of Mr. Becher's visit. His notes, however, give no par-

ticulars as to whether the reef had been picked up below the depth at which it cut out. In 1897 22 tons of ore are officially recorded as yielding 63ozs. of gold, or at the rate of 2·86ozs. per ton.

MARQUIS, G.M.L. 62L.—A disused and inaccessible shaft is situated at a point 13 feet from the north-east angle of the lease, and is traversed by a small reef parallel to that in the adjoining property on the north. About 100 feet south from the north-east angle is a well-defined reef, shown on the geological map, underlying at a high angle to the north-west, but no work has been done upon it.

There are one or two other abandoned leases and quartz claims in the vicinity of Kadjebut Creek to the west of the South Dromedary G. 16. The position of these properties is shown on the 40 chain lithograph L 76, issued by the Department of Mines.

GOLDEN EAGLE, G.M.L. 77L (formerly Alexandra, G.M.L. 71L).—A great deal of desultory work has been carried out upon what were evidently distinct veins, but all the workings are inaccessible at the present time. According to the official records, small crushings from this lease took place annually from 1897 to 1901, but although the total quantity of gold, under 500ozs., so obtained was small, the average per ton was over four and a-half ounces. There would thus seem to have been some very rich shoots met with in the course of the work.

Table showing the Yield of the Golden Eagle Reef.

Year.	Ore crushed.	Gold therefrom.	Rate per ton.
	tons.	ozs.	ozs.
1897	21·00	52·50	2·50
1898	57·50	290·20	5·04
1899	12·70	79·60	6·26
1900	12·00	64·55	5·38
1901	2·75	6·10	2·22
Total	**105·95**	**492·95**	**4·65**

REWARD CLAIM, 33L.—A small abandoned lease on the eastern bank of Kadjebut Creek, and lying about three-quarters of a mile to the south-east of the Golden Eagle. An east and west vertical reef has been opened up by a shaft which is inaccessible at the present time, hence no information as to the character and behaviour of the reef underground can be obtained. There appear to be no records of any crushings from this property, unless they are included under the heading of the yield from sundry claims.

The following synoptical table gives the total gold yield of the reefs of Nullagine, in so far as such may be obtained from official statistics:—

Synoptical Table showing the Yield of the Nullagine Reefs up to the end of 1904.

Name of Reef.	Ore crushed.	Gold therefrom.	Rate per ton.
	tons.	ozs.	ozs.
Day Dawn	266·00	702·70	2·64
Fisher's Reward	20·00	56·60	2·83
Golden Eagle	105·95	492·95	4·65
Great Eastern	170·00	202·75	1·19
Great Eastern Extended	190·00	224·40	1·18
Promise	30·00	90·00	3·00
Sunrise No. 1	28·00	14·00	·50
Victory	121·00	421·10	3·48
Victory East Extended ...	285·00	1,229·80	4·31
Victory Extended ...	22·00	63·00	2·86
Total	**1,237·95**	**3,497·30**	**2·82**

Auriferous Conglomerates.

Mining operations have, up to the present, been confined exclusively to the outcrop of the conglomerates and to very limited and shallow depths; but work, however, has been carried sufficiently far to enable some idea of the conditions governing the gold deposition being ascertained. The conclusions to be drawn from these data may have some influence upon the practical development of the field. The gold contents of the conglomerate are small, not amounting to more than 3,217·29ozs. derived from the milling of 5,167 tons of ore, or at the rate of ·62oz. per ton.

Of the different areas in which the conglomerate has been worked, the largest quantity of gold, so far as may be judged by the official figures, appears to have been obtained from the workings now embraced by the Grant's Hill Lease 122L. (*vide* the plan of the Nullagine Conglomerate Gold Mines, Plate II.) The returns from this demonstrate that 3,433 tons of ore yielded 1,780·24ozs. of gold, or at the rate of ·52oz. per ton.

The auriferous conglomerate, which has already been shown to be of sedimentary origin, is made up of rounded and subangular fragments of the strata identical in character with that forming the underlying Mosquito Creek Series. Certain portions of the conglomerate are marked by the presence of abundant iron pyrites, and its oxidation products [**5802**, **5806**]. It is, however, in the oxidised zone of the conglomerate that any mining has, up to the present, been carried on.

In 1897, samples of the auriferous conglomerate were examined in the Survey Laboratory and have been thus described:- -

"A specimen [190] typical of the finer-grained portions of the rock in its upper decomposed portions. It consists of subangular fragments of quartz, ironstone and shale, cemented together by ironstained kaolin, containing numerous cuboidal cavities at one time filled by pyrites crystals, as shown by the numerous pseudomorphs of limonite contained by them. . . . . It assays 1oz. 6dwts. of gold. . . . . A similar but less ferruginous variety, [191], showed no cavities vacated by pyrites, and is much coarser in grain, some of the fragments of quartz being 3 inches in length; it assays 2ozs. 1dwt. of gold per ton."*

Another variety [192] made up of large pieces of felstone, with smaller fragments of quartz embedded in a kaolinic matrix, assayed 10dwts. of fine gold and 5ozs. 4dwts. of coarse gold per ton.

A noteworthy feature in the conglomerate is the occurrence of pyrites and its oxidised representatives. In the unoxidised portions [3718, 5801, 5802] the pyrites occurs both as crystals, grains, and rounded or pebble-like forms. A photograph of a small but characteristic form [5802] is shown in Photograph "C." Some of the pyrites nodules measure an eighth of an inch in diameter, though from the size of some of the hematite pebbles there must be some which reach as much as three-quarters of an inch in diameter. A photograph of one of these hematite pebbles [5801] forms Photograph "D."

Considerable interest attaches to the occurrence of these rounded pebbles and pellets of pyrites and hematite in that they have been held to indicate a detrital character as well as ascribing a similar origin to the gold, which seems invariably to be associated with the occurrence of the ores of iron in the conglomerate.

A radiate fibrous structure can be detected in some of the oxidised conglomerates [5801] when the hematite pebbles exhibit fractured surfaces.

In some portions of the conglomerate [190] these hematite fragments make up fully one-half of the rock. The gold [1509, 3167] in the conglomerate almost invariably occurs in or lining the sides of these cavities which have been left by the removal of the iron ore. All its characters point to the gold having been left where it is now found by the oxidation of the pyrites.

The evidence, so far as it goes, respecting the origin of the gold in the Nullagine conglomerate seems to indicate that it is a secondary, and not an original constituent, and further that the primary source of the gold is the quartz reefs which occur in the underlying formation.

From the known occurrence of auriferous quartz reefs, which furnished no small portion of the pebbles of certain portions of the

* Annual Progress Report of the Geological Survey for the Year 1897. Perth: By Authority: 1898, p. 48.

Photo.: E. S. Simpson.

Rounded Pyrites Pebble in Conglomerate, Nullagine Series.

PHOTO.: E. S. SIMPSON.

Rounded Hematite Pebbles in Conglomerate, Nullagine Series.

deposit, it is of course quite conceivable that a certain amount of detrital gold forms part of the conglomerate, but there are obviously no means of ascertaining what is the proportion of primary to secondary gold.

There seems, however, good reasons for believing that by far the bulk of the gold, together with the pyrites, was introduced by solutions percolating down the most porous portions of the conglomerate, this condition being facilitated by the downward inclination of the bed-rock, and, possibly, accentuated in part by the folding which the strata have undergone.

The intrusion of felsite into the lower portion of the conglomerate (Plate II.), and the volcanic phenomena of which it formed a part, may possibly have resulted in the formation and circulation of the mineralising solutions, and also the deposition of the gold.

There is no evidence that the diabase dyke and the fault (Plate I.) have had any beneficial effect upon the gold contents of the conglomerate, but the fact remains that it is only in that portion of the formation lying between these two lines of fracture that any gold has hitherto been found. It is also noteworthy that the base of the Nullagine Series has only proved auriferous in those places where it lies upon that portion of the underlying formation which carries auriferous deposits. It may be noted, also, that over that portion of the formation from which the conglomerate crushings have been obtained numerous dryblowers have been at work for a number of years, and have obtained a considerable quantity of gold, of which the published figures afford no clue, for much of it in the early days was probably never officially reported.

Probably one-half of the alluvial gold from Nullagine, shown in the figures on page 16, may be legitimately claimed as having been derived from the escarpment of the conglomerate.

The high assays [**190**, **191**, **192**] alluded to are the exception, and merely indicate the occurrence of unusually rich shoots in portions of the conglomerate.

No attempt was made to sample any portion of the conglomerate workings, with the view of arriving at the value of the deposits, but six samples (which seemed to be characteristic of the type of deposit), collected during the course of the fieldwork, were assayed in the Departmental Laboratory, with the following results:—

[**5800**].—Grant's Hill Lease 122L. Oxidised Conglomerate in which the iron had been entirely leached out. Gold, 6dwts. 23grs. per ton.

[**5801**].—Grant's Hill Lease 122L. Oxidised Conglomerate, with abundant hematite kernels. Gold, 2dwts. 11grs. per ton.

[**5806**].—Dean's Hill, Mineral Reward Claim 6L. Oxidised Conglomerate with hematite kernels (some portions of this conglomerate show free gold). Gold, 4dwts. 2grs. per ton.

[5802].—Freak of Nature, G.M.L. 121L. Pyritous sulphide conglomerate. Gold *nil*.
[5803].—North-west of the Success, G.M.L. 119. Very slightly pyritous conglomerate. Gold *nil*.
[5804].—North-west of the Success, G.M.L. 119. Non-pyritous conglomerate. Gold *nil*.

To arrive at the value of the deposits, as can be readily understood, is an exceptionally difficult matter, but the figures of the output afford some idea of the yield of those isolated portions of the conglomerate which were deemed worth working.

The records of production of the conglomerates, given in the table on an earlier page (p. 26), seem to indicate a general decrease in the yield, the latest crushing of 777 tons returning gold at the rate of ·12oz. per ton.

Fluctuations in the gold yield per ton are, of course, only to be expected, but it cannot be said that the average of all the crushings recorded is any index to the value of the whole of the conglomerate series, if worked upon a large scale. It would probably prove to be a very low grade, and possibly so low as to render remunerative working, unless under the most favourable economic conditions, impossible.

The known occurrence of such an extensive formation as the Nullagine Series has proved, by mapping, to be and the fact that it has been shown to contain considerable quantities of gold in localities where the requisite and qualifying conditions for deposition obtain, would seem to encourage efforts in the direction of carefully prospecting other parts of the basal members of the series in the district.

Such prospecting should be a relatively easy task, seeing that it has already been shown that the auriferous portions of the conglomerate have invariably proved to be those which are the most ferruginous, hence the search for ironstained conglomerates near the base would seem to be the lines upon which such efforts should tend.

The Mines.

Grant's Hill, G.M.L. 122L.—A considerable amount of *bonâ fide* work has been done upon the western angle of the lease, as may be seen by an inspection of the plan of the Nullagine Conglomerates Gold Mines (Plate II.)

Fairly extensive workings on the south side of the tramline which connects with the battery have been carried on in a bed of coarse conglomerate, the exact thickness of which does not appear to have been determined. The conglomerate (or boulder bed) contains large boulders of flat-sided quartz, siliceous conglomerate, and other rocks occurring in the vicinity. This portion of the workings lies in the oxidised zone of the conglomerate which contains cellular portions from which iron pyrites has weathered out [5800]. This sample assayed in the departmental laboratory 6dwts. 23grs. of gold per ton.

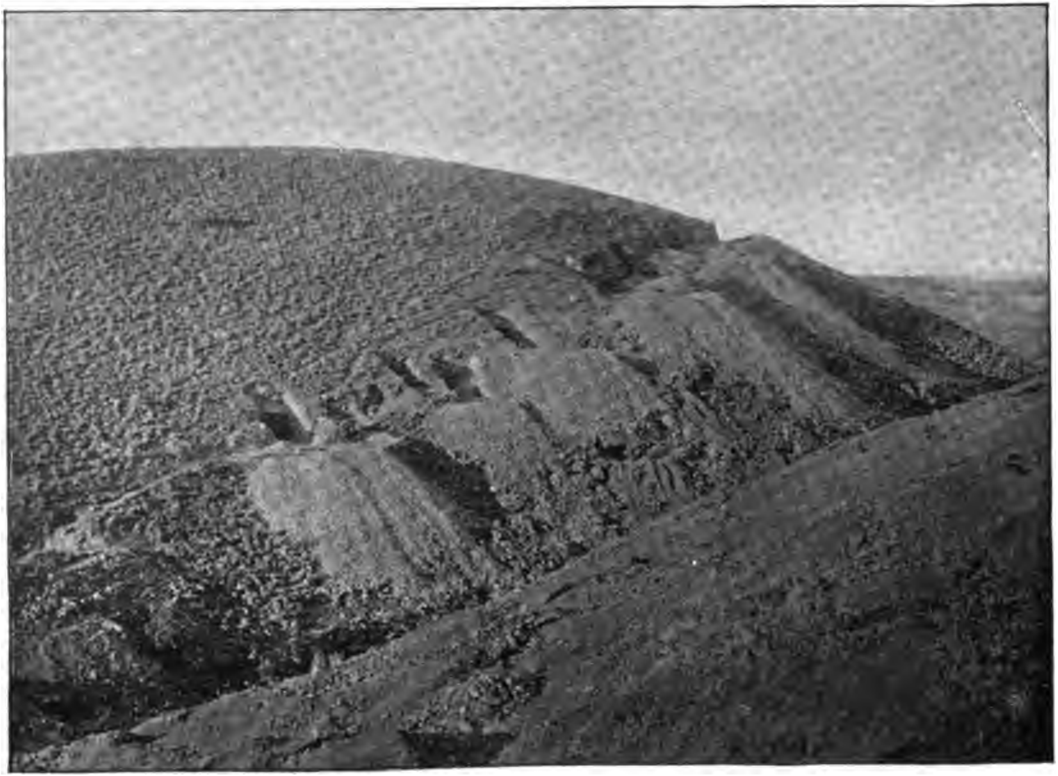


PHOTO.: S. J BECHER.

The larger portions of the workings, however, occur on the southern slopes of Grant's Hill, which lies on the north side of the creek which drains the gully in a westerly direction. (Photograph "E.")

A good deal of ore must have been taken out at one time or the other, for the workings extend for some considerable distance round the slope of the hills. The larger portion of the work has been carried out on a bed of conglomerate, underlying generally west-north-west, rising gradually up and along the hillside at an angle of about 40 degrees, and as the plan (Plate II.) and statistics show, a good deal of ore must have been taken out.

A fault with a very small displacement occurs in one portion of the workings, and it appears to be parallel to the main fault shown on the geological and mining maps (Plates I. and II.)

A thickness of only from three to four feet of the conglomerate has been worked. So far as can be gathered from the official statistics, the returns from what is now Grant's Hill are set forth in the table:—

Table showing the Yield of the Grant's Hill Conglomerate.

Year.	Ore crushed.	Gold therefrom.	Rate per ton
	tons.	ozs.	ozs.
Previous to 1897	109·00	147·00	1·35
1897	*Nil.*	*Nil.*	—
1898	275·00	382·35	1·39
1899	462·00	343·25	·74
1900	152·00	70·50	·46
1901	1,358·00	614·53	·45
1902	300·00	128·51	·42
1903	777·00	94·10	·12
1904	*Nil.*	*Nil.*	—
Total	**3,433·00**	**1,780·24**	**·52**

To what may be called the Grant's Hill conglomerate should be added the small crushing of 85·40 tons, which yielded in 1899 40·70ozs. of gold, or at the rate of ·47oz. per ton, from what was originally known as the Trinity No. 1 South, G.M.L. 422, and subsequently Grant's Hill South, G.M.L. 68L.

This old twelve-acre lease adjoined the present Grant's Hill lease on its southern boundary, and apparently included the ground now occupied by the "Residence" shown on the plan of the Nullagine Conglomerates Gold Mines (Plate II.). The conglomerate from which the crushing was taken occupied the crown and the north-western slope of the hill lying to the east of the main fault. This hill formed a very rich field for dryblowers in the early days of Nullagine.

This additional crushing brings the total return from the Grant's Hill conglomerates up to 1,820·94ozs., obtained from the milling of 3,518·40 tons of ore, or at the rate of ·51oz. per ton.

Freak of Nature, G.M.L. 121l.—What is now the Freak of Nature Lease includes the ground originally embraced by the Freak of Nature, G.M.L. 208, the Freak of Nature Extended, G.M.L. 21, and the Exchange, G.M.L. 18.

The most easterly working near the eastern angle of Grant's Hill was originally known as Neale's No. 3 Underlay. Work in this shaft had been confined to a bed of conglomerate, 3 feet in thickness, underlying to the north-west at angles varying from 18 to 20 degrees. The late Mr. Inspector Becher sampled this conglomerate, and reported the prospects to be "fair."

It would seem that this conglomerate is on the same horizon as that exploited in the adjoining Grant's Hill Lease.

The next working, on a slightly lower horizon, was known as Hewett's Shaft, and a little work was done upon a conglomerate from 2 feet 6 inches to 3 feet 6 inches in thickness; from this locality Mr. Becher also obtained "fair" prospects. This conglomerate appeared to be much more kaolinic than that in Neale's shaft.

Another shaft, shown upon the plan, had been put down upon a conglomerate, on a lower horizon, but no particulars respecting it are available.

There appears to be no record in the statistics of any crushings having been made on the old Exchange Lease; should any have been recorded they may be included in the yield from sundry claims, etc. It does not, however, appear from the conditions of the workings that any very large body of ore can have been taken out. From that portion of the present Freak of Nature Lease, which embraces the old Freak of Nature, G.M.L. 208 (1l), practically no work seems to have been done.

At a point on the northern bank of the main creek, near the north-eastern boundary of the lease, is a cliff of unoxidised pyritous conglomerate, which is distinctly banded.

A typical sample [5802] of this pyritous conglomerate, when assayed in the departmental laboratory, yielded, however, no trace of gold.

On the south-eastern portion of the lease, lying to the south of the pyritous conglomerate previously described, and in the ground originally embraced by the old 5-acre lease, Freak of Nature Extended, a big tunnel (Plate II.) has been put in, upon a boulder conglomerate. Judging by the present condition of the workings there seems to have been a good deal of work done, and a fairly large quantity of stone taken out. Mr. Becher's note-book indicates that the result of his sampling was that the prospects were "poor."

There are no official records of the yield of this portion of the property.

Success Extended, G.M.L. 120L.—This 24-acre lease embraces part of the old Rejected, G.M.L. 414, Success, G.M.L. 352, and the Freak of Nature, G.M.L. 208. It is, however, only in the old Success and the Rejected that any mining work has been done.

The small patch lying between the 80 and 90 feet contours, in the northern portion of the ground, form the Rejected workings; in reality merely an open work on the outcrop of a bed of conglomerate.

Operations, however, have been principally confined to the old Success ground, and the extent of the open-work is indicated on the mining plan which forms Plate II. So far as may be gathered at the present time the auriferous conglomerate, which did not differ from any of the other auriferous beds, varied in thickness from 18 inches to two feet. The table below gives the total gold yield, so far as can be gathered from the official figures; the 547 tons of ore crushed were in all probability obtained from this portion of the lease.

Table showing the Yield of the Success Extended Conglomerate.

Year.	Ore crushed.	Gold therefrom.	Rate per ton.
	tons.	ozs.	ozs.
Previous to 1897	32·00	42·00	1·31
1897	*Nil*	*Nil*	...
1898	305·00	349·25	1·14
1899	110·00*	115·00	1·04
1900	*Nil*	*Nil*	...
1901	100·00	33·00	·33
Total	547·00	539·25	·98

* The 96 tons yielding 34·40ozs. from the Cook's Hill workings, credited in the official return to the Success Lease, are not included in this total, but are included in the yield of M.R.C. 6L.

Success, G.M.L. 119L.—This 24-acre lease, as it now stands, includes within its boundaries the old Barney's Hill United, G.M.L. 276 (upon which most of the work has been done), and a portion of the Success, G.M.L. 352.

The conglomerate worked on Barney's Hill lies at about the highest altitude of any of the beds at present opened up, being about 100 feet vertically above that in Grant's Hill. The workings lie pretty nearly upon the summit of the hill and along its southern slopes; the bed has been stripped along its outcrop for some distance round the southern and western slopes, and a vertical shaft 25 feet in depth has been sunk, intersecting a drive put in along the conglomerate for some distance from the outcrop.

Over three hundred tons of ore have been raised from the Barney's Hill workings. The figures given in the table as being

the yield of the present Success Lease were derived from ore obtained exclusively from the Barney's Hill workings.

Table showing the Yield of the Success Conglomerate.

Year.	Ore crushed.	Gold therefrom.	Rate per ton.
	tons.	ozs.	ozs.
Previous to 1897	80·00	100·15	1·25
1897	246·00	228·00	·92
1898	12·00	23·10	1·92
Total	**338·00**	**351·25**	**1·03**

Barney's Hill No. 1 North, G.M.L. 24L (330).—This six-acre lease, which was abandoned in 1897, embraces the workings (Plate II.) lying near the western angle of G.M.L. 119L. Operations have been confined to a bed of very coarse ferruginous conglomerate, containing very large ellipsoidal boulders. At a slightly lower level on the north side of a gully flowing southwards from the south-west angle of G.M.L. 119L is a vertical shaft, 50 feet in depth, in which five or six feet of water were standing. This shaft, which was inaccessible, had been carried down through conglomerate of the usual type, and, judging by the material at grass, it contained a little pyrites. A characteristic portion of the pyritous conglomerate [**5803**] yielded no gold on assay in the official laboratory.

The only returns from the Barney's Hill United Lease appear to have been previous to 1897, when a small crushing of 20 tons yielded 25ozs. of gold, or at the rate of 1·25ozs. per ton. These figures indicate that portions of the conglomerate, in this part of the field, are auriferous.

Mineral Reward Claim, 6L.—This Reward Claim, which comprises an area of 320 acres, includes within its boundaries the old leases:—Golden Crown, G.M.L. 365 (31L); Beaton's Hill, G.M.L. 373 (37L); Cook's Hill, G.M.L. 412 (47L); Rejected No. 2, G.M.L. 416 (50L); together with parts of Golden Promise No. 1, G.M.L. 67L, and Central No. 1, G.M.L. 69L.

Near the easternmost angle of G.M.L. 119L, and to the north of Dean's Hill, are a series of extensive workings upon what was originally the Golden Crown G.M.L. 365, at an altitude of over 200 feet above the low ground at the base of the formation. All the ground on the flanks of the hill below these workings has been dryblown, and, during Mr. Inspector Becher's term of office, the average winnings from this source are stated to have amounted to about 18dwts. per man per day. The conglomerate, which lies in the locality practically horizontally, is of the usual ferruginous type, containing large pellets of hematite. A typical sample of this highly ferruginous variety from the open-work [**5806**] assayed in the

departmental laboratory gold at the rate of 4dwts. 2grs. per ton. The total returns from the Golden Crown workings, as shown in the table below, gives the yield as 189·90ozs. obtained from the milling of 223·60 tons of ore, or at the rate of ·84oz. per ton.

What is known as the Cook's Hill workings are situated due east of W.R. 2L. Cook's Hill is said to have derived its name from Mr. Nat. Cook, who is credited with being the first discoverer of gold at Nullagine in 1886. A good deal of work must have been done at one time or another, but as operations have been abandoned for some considerable time there is little to be seen.

By far the larger portion of the hill appears to have originally been covered with a gritty and ferruginous sand (the residual decomposition product of a sandstone) underlaid by a kaolinic deposit which carried waterworn boulders. It is noteworthy that while the material from the hill was being crushed several small diamonds were met with in the battery boxes; reference however will be made to this subject on a later page. The Cook's Hill deposit lies not very far from the base of the Nullagine Series. The total returns from the Cook's Hill workings, as shown in the table below, give the yield as being 140·10ozs. obtained from the milling of 348 tons of ore, or at the rate of ·40ozs. per ton. In this return an effort has been made to credit Cook's Hill with the yield actually obtained from the ore raised.* The return from the Diamond Reward Claim, M.R.C. 6L, as shown in the general table at the end, is really the result of the ore obtained from the Cook's Hill workings, and there seems to be good reason for believing the 1899 return from the Success Lease 27L includes 96 tons of ore from this same source. This latter yielded a return of 34·40ozs. of gold, or at the rate of ·36ozs. per ton. The workings on Beaton's Hill, which lie to the west of those last described, the hill upon which work has already been carried out, comprises about four acres, and is covered by a deposit of laterite stated to be about ten feet in thickness. Beneath the laterite occurs a more or less variable thickness of almost horizontal beds of sandstone and conglomerate. The bed which was worked lies near the base of the hill, and is said to rest directly upon a bedrock of slate, and the gold is said to have been traced thereto by the alluvial workers in the adjacent gully on the north.

Two shafts, now inaccessible, have been sunk to depths stated to be 35 and 40 feet respectively, and levels driven therefrom.

Mr. Beaton, one of the original holders of the ground, and after whom the hill is named, is stated to have worked a considerable distance in under the hill, and to have taken out a large quantity of gold by crushing the material roughly by hand, screening it, and sluicing it at the river. There appears, however, to be no official

* The late Mr. Becher's note-books, 1896, state that "since first worked Cook's Hill has yielded about 4,000ozs. of gold." There is no reason for doubting the accuracy of this statement, but it is quite clear that this amount has not been officially recorded in the statistics, and may possibly never have been reported to the Government.

record of the yield from the old Beaton's Hill Lease, and in all probability any returns therefrom have been included in that from sundry claims.*

Table showing the Yield of the Conglomerates of the Mineral Reward Claim 6L.

Year.	Name of Lease.	Ore crushed.	Gold therefrom.	Rate per ton.	Total Ore crushed.	Total Gold therefrom.	Average rate per ton.
		tons.	ozs.	ozs.	tons.	ozs.	ozs.
Previous to 1897	Golden Crown, G.M.L. 31L	32·60	50·90	1·56			
1898 ...	Do. do. ...	191·00	139·00	·72	223·60	189·90	·84
1898 ...	Cook's Hill, G.M.L. 47L ...	22·00	26·30	1·19			
1899 ...	Do. do. ...	96·00	34·40	·36			
1900 ...	Do. do. ...	230·00	79·40	·34	348·00	140·10	·40
	Total				571·60	330·00	·49

Golden Promise, G.M.L. 380 (39L, and subsequently Golden Promise No. 1, 67L.)—The abandoned workings upon what was originally embraced by this lease are coterminous with the north-western boundary of the Mineral Reward Claim, 6L (Plate I.), and at an altitude of about 180 feet above the general level of the plains. A vertical shaft, 20 feet in depth, had been put down through conglomerate and intersected the open-works at a lower level. The auriferous portion of the conglomerate was a ferruginous band varying from 15 inches to 2 feet in thickness.

The following table gives the yield of the crushings:—

Table showing the Yield of the Golden Promise Conglomerate.

Year.	Ore crushed.	Gold therefrom.	Rate per ton.
	tons.	ozs.	ozs.
1897	84·00	68·65	·81
1898	88·00	81·20	·92
Total	172·00	149·85	·87

Sundry Claims from the District generally.—In addition to the returns given above in connection with sundry claims, which it is impossible to specify individually, there have been recorded over 6,000ozs. of gold. These figures are given in such

* The late Mr. Becher's note book, 1896, states:—"Return, September, 1896, 1 ton, yielding 2ozs. 2dwts. 12grs. Since Beaton's Hill was first worked it has yielded about 3,000ozs. of gold." This amount does not appear to have been officially recorded in the statistics, and may possibly never have been reported to the Government.

detail as is possible in the table below. There are, however, no means of ascertaining what proportion of these figures are to be credited to that portion of Nullagine embraced by the geological map (Plate I.); it is, however, possible that they include returns from the Elsie, Mosquito Creek, Nullagine, and 20-mile Sandy, which centres are included in the "Nullagine District," as defined by the Mines Department.

Table showing the Yield from Sundry Claims, Nullagine.

Year.	Ore crushed.	Gold therefrom.	Rate per ton.
	tons.	ozs.	ozs.
1897	100·00	143·65	1·43
1898	92·00	213·90	2·32
1899	1,066·70	2,695·95 *38·45	2·52
1900	1,008·60	2,433·30 *11·00	2·41
1901	248·25	336·54	1·35
1902	293·05	343·67	1·17
1903	145·90	609·30	·41
1904	830·65	1,308·65† *23·75†	1·57†
Total	3,785·15	8,158·16	2·15

* Specimens. † Fine ozs.

Diamonds.

The occurrence of small diamonds at Nullagine having been brought under the notice of the Government, a report was obtained on the subject by the then Premier from Mr. Fred. F. Groom in the year 1896.* From Mr. Groom's report it appears that the greater number of the most valuable diamonds were washed out of the conglomerate forming Brook's Hill, which was being treated for gold, and others were found in the stamper boxes after crushing a few tons of the conglomerate. Mr. Groom states: "There is no doubt, in my opinion, that the diamonds are enclosed in the conglomerate, . . . and such as have been found by diggers in washing for gold have been released by the gradual decay of the rock . . . On the last day of my stay in Nullagine, I was present at the cleaning up of the battery after crushing about two tons of stone taken from the hill . . . On carefully panning off the gravel left in the stamper boxes nine small stones were found, varying from the size of a pin's head to a pepper-corn, or from $\frac{1}{16}$ to $\frac{1}{2}$ carat in weight. I put the lot into the scales, they weighed $1\frac{1}{2}$ carats, and it took the four largest to weigh one carat. I was informed that

* Report of a visit to Nullagine, Pilbara District, to examine the country reported to be diamond-yielding. Appendix 4. Report of the Department of Mines for the Year 1895. Perth: By Authority, 1896, p. 27.

Mr. Brooks found one diamond for which he obtained £76, another he sold for £28. These, with one other, valued by the finder at £12, were all the diamonds I could hear of as having been of any value; the last-mentioned stone was described as being bright yellow."

During the course of my examination of the district no diamonds came under my notice, there are, however, in the collection of the Western Australian Museum (*a*.) four small diamonds presented by Messrs. Brook Bros. in 1896, and (*b*.) four small diamonds taken from the battery boxes when cleaning up a crushing of conglomerate, one from Cook's Hill, presented by Mr. Inspector S. J. Becher in 1896. The returns of a crushing of 230 tons of conglomerate from the Mineral Reward Claim 6L in 1900 show, in addition to 79·40ozs. of gold, twenty-five small diamonds, the value of which, however, is not stated. From the particulars given above it seems perfectly clear that the presence of diamonds in the conglomerates near the base of the Nullagine Series is authentic. The occurrence of such renders it possible that they are not isolated instances, though the interest is at the present time more scientific than commercial.

Name of Lease.	Number of Lease. Marble Bar Number.	L. Number.	Owner.	Remarks.
Day Dawn	278	17	Doherty and Party ..	Abd., 14/8/99 ..
Do. No. 1 S.	388	43	J. Isdell	Abd., 24/12/97 ..
Do. North ..	418	52	Do.	Ftd., 24/12/97 ..
Promise	331	25	Farley & White ..	Surr., 19/7/97 ..
Fisher's Reward ..	..	65	Fisher & Martin ..	Abd., 31/3/97 ..
Try Again	..	66	Walters Nicholls ..	Abd., 21/4/97 ..
Victory	383	42	Geo. Holcombe ..	Surr., 3/5/96 ..
Do. Extended	417	51	Do.	Surr., 3/5/98 ..
Golden Eagle	..	77	Johns & Smythe ..	Late 71L, Alexandra
Do. No. 1 E.	419	53	Royer, Ahern, etc. ..	Ftd., 9/4/97. Later 70L, New Victory Extended
Victory East Extd.	424	56	W. Extd. Volunteer Pros. Association	Ftd., 14/7/99 ..
Walter's Folly ..	..	99	Alfred Royer	Voided, 6/9/01. Late 56L
Victory	..	134	Aikman & Giles ..	Late 99L .. ..
Marquis	..	62	Maher, Wiberg, etc.	Ftd., 25/6/97 ..
Sunrise No. 1 ..	429	57	Turner & Travis ..	Abd., 18/1/97 ..
Sunrise	430	58	Aikman & Higgs ..	Abd., 29/1/97 ..
Gt. Eastern No. 1 ..	423	55	Garland & McKenna ..	Abd., 18/9/96 ..
Gt. Eastern Extd. ..	..	61	Doherty & Jenkin ..	Abd., 19/1/99 ..
Great Eastern ..	..	59	Isdell, McKenna, etc.	.. ..
Do. No. 1 ..	..	72	Isdell, Connolly, Holcombe	Abd., 1/12/97. Part in 75L
Scottish Chief ..	..	64	Eatch, Townsend, etc.	Abd., 20/1/97 ..
Enterprise	..	76	Jenkin, Garland, etc.	Ftd., 13/10/99. Part of 40L
				Total .. ..

B.—WARRAWOONA.

(With a Geological Sketch Map and three Mine Plans.)

General Geology.

The mining centre of Warrawoona lies about 15 miles from Marble Bar, and embraces the south-eastern extension of that belt of auriferous rocks which form the Marble Bar, Yandicoogina, and Mount Elsie Zone, to which reference has been made in a previous report.*

The district of which Warrawoona is the centre is formed of a lofty serrated razor-backed ridge (with several minor parallel ones) trending generally north-west and south-east. It is upon the southern slopes of the main ridge, and what perhaps may be conveniently called the foothills, that all the auriferous quartz reefs occur. The general trend of these ridges has been determined by the outcrop of the siliceous rocks of which they are everywhere made up.

Several important watercourses occupy the longitudinal valleys (carved out of the softer strata) between the different ridges, whilst those creeks which breach them almost at right angles to the general strike of the schists afford many excellent sections. They thus shed light upon many obscure points in connection with the geological features of the district. The plateau which extends for miles on either side of what may be called the main axis owes its relatively smooth and rounded contour to the general homogeneity and practically equal weathering of the rocks by which it is underlaid, *e.g.*, granite, etc.

The geological formations of the area embraced by the Geological Sketch Map of Warrawoona (Plate III.) are represented by a series of sedimentary rocks, quartzites, and conglomerates, many of which have been converted into quartz schist, mica schist, etc., by dynamic agencies. Associated with these undoubted sedimentary strata are a series of igneous rocks which have likewise been rendered partly schistose by the same causes. The exact relation these igneous rocks bear to the sedimentary series has not been worked out, a problem which would perhaps be difficult in this particular portion of the district. The southern portion of the district is occupied by granite, which appears to have been brought into position by a fault, trending generally north-west and south-east.

Somewhat akin to the southern granitic mass are those dykes and masses of felspar-porphyry which occupy the northern limits of the map; in all probability these latter have some intimate connection with the large area of granite which occupies the country to the north of that embraced by the Warrawoona Map. There seems however to be strong reasons for believing the granite to be intrusive into what may conveniently be termed the schists, and that portions of it have been affected by earth movements of varying degrees of intensity after the intrusion took place.

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* Bulletin No. 15, p. 33 et seq.

In addition to these rocks, the field is traversed by a remarkably persistent series of north-west and south-east greenstone dykes. These dykes, which have been mapped with some degree of accuracy, traverse the centre of the auriferous portions of Warrawoona, approximately at right angles to the general trend of what may be called the auriferous zone. Besides these relatively newer greenstone dykes, there are others which are intimately associated with the older rocks of the district. These older dyke rocks are often rudely cleaved and foliated, and seem to occur in intimate connection with, or parallel to, the principal structural lines of the district, viz., north-west and south-east. These older cleaved or foliated dykes can be seen in many places to be pierced almost at right angles to their general trend by the newer or uncleaved series.

Within the area embraced by the map, there is a large development of those laminated or banded quartz veins which form such conspicuous features in this district. These, owing to their economic importance, have been laid down upon the map with a considerable degree of accuracy. One conspicuous band traverses the whole length of the district, viz., six miles, and forms the centre of the main auriferous zone, which latter is of considerable longitudinal extent, though averaging only about 20 or 30 chains in width.

Of the different rocks occurring in the Warrawoona area, not much can be said, in the present state of our knowledge, of their relative ages, nor their true position in the geological time scale.

The following is a list of the various rock groups arranged in tabular form:—

Warrawoona Beds. Age undetermined (? Archæan)	(*a.*) Altered Sedimentary Series (quartzites, conglomerates, quartz, and mica-schist, etc.)
	(*b.*) Metamorphic Igneous Rocks (greenstone, magnetite, and serpentinous schist, and more or less allied sheared basic igneous rocks)
Granite and Felspar Porphyry.	
Basic Dykes	(*a.*) Newer
	(*b.*) Older

Warrawoona Beds.

The strata of the Warrawoona Series form part of that auriferous zone which includes Marble Bar, Yandicoogina, and Mount Elsie, and to which reference has already been made in a former report.* In the Warrawoona neighbourhood, however, much better opportunities for investigating the strata present themselves than in any other portions of the district yet examined.

An examination of the district, which is of great importance by reason of its gold yield, shows that the Warrawoona Beds can be separated into two distinct portions sharply differentiated from each other, viz., an acidic and a basic series. The acid series is made up of highly siliceous beds, dipping at varying angles to the

* Bulletin No. 15, p. 33 *et seq.*

north-east and trending generally north-west and south-east. The beds, which there are very good reasons for believing to be of sedimentary origin, consist of fine-grained flaggy quartzites, sheared conglomerates which still retain traces of their original character, mica and quartz schists, together with certain other fine-grained siliceous rocks which seem to have lost all trace of their original character. There are, in intimate association with these, certain other acidic rocks, which may eventually prove, on closer examination, to be highly-sheared felsites; it has however not been found possible, owing to the small scale of the map, to delineate the area over which these doubtfully acidic igneous rocks extend; it is, however, but small.

In hand specimens, this doubtful rock [5788] is in reality a quartz-sericite schist, with eyes or lenticules of a fairly soft mineral around which the finer foliation of the matrix sweeps in very graceful curves. The mineral forming these eyes has been examined both chemically and microscopically by Mr. E. S. Simpson, who reports that "they appear at one time to have been single crystals of probably potash-felspar, but are now completely altered into a mixture of at least three minerals, viz., free quartz; a non-hydrous crystalline silicate of alumina, probably andalusite; and a hydrous silicate of alumina and alkalies, probably a mica. The specific gravity of these 'eyes' is variable but averages 2·85. Their average composition is:—

Silica, SiO_2	76·0
Alumina, Al_2O_3	21·4
Ferrous Oxide, FeO	·3
Lime, CaO	*Nil*
Magnesia, MgO	Trace
Potash, K_2O	·4
Soda, Na_2O	·3
Combined Water, H_2O	1·6
	100·0"

Examined under the microscope these porphyritic crystals are found to be shattered and broken, and their edges present that peculiar peripheral granulation so characteristic of crystals and fragments which have been subject to intense crushing. A micro-photograph of one of these shattered and broken crystals forms Fig. a, Photograph "H" (facing page 72.) The matrix in which the larger crystals are embedded presents a fine mosaic of quartz, felspar, and a little sericitic mica through which are streams of numerous yellowish brown crystals. These crystals which occur in the form of short, and sometimes geniculated, pear or kite-shaped prisms, with straight extinction under crossed nicols, are in all probability rutile. It is difficult, with the evidence at present available, to be sure of the exact nature of the original rock, but it may possibly have been produced by the crushing of a felspar porphyry. Unaltered felspar porphyries do occur in the country just to the north of this, hence it is possible that this rock may be merely a transmitted variety of them.

The specimen, a quartz sericite schist [5760], is another variety of a rock identical in many respects with that last described, except that there are no large porphyritic crystals. Streams of rutile are common, in addition to numerous colourless acicular crystals of what seem to be apatite.

A quartz schist [5761] from near the Ironclad Battery, M.A. 1, consists microscopically of a mass of irregular interlocking grains of quartz, with irregular patches arranged in the form of bands, of what under crossed nicols is neither more nor less than a fine quartz mosaic. The quartz exhibits undulose extinction. A little sericitic mica occurs in places.

Another quartz schist [5762] from a different portion of the mass, when examined under the microscope consists of a very fine-grained mass of quartz, showing undulose extinction, together with a little sericitic mica, the foliæ of which are often very much distorted.

A fairly fine-grained quartzite [5764] which under the microscope is found to contain numerous fairly large angular and sub-angular quartz grains set in a much finer-grained quartz mosaic. This rock contains numerous brown patches and strings of mica (?) together with a little pyrites.

Associated with these quartzites and quartz schists is a very calcareous rock [5765] which outcrops near the Ironclad Battery. In hand specimens the rock is of a pale salmon colour, is distinctly banded, weathers very much like a limestone, and effervesces briskly upon the application of dilute acid. An analysis of this rock is given in the table on page 66. Very little can be made out by microscopic examination, even with a $\frac{1}{4}$-inch objective, and it is not quite clear whether the rock is a limestone or merely an extreme phase of the alteration of one of the igneous rocks of the district. The field relations however seem to point to its being distinctly interbedded with the quartzites and quartz sericite schists.

A short distance north of the Seven Dials, just outside the limits of the geological map, is a conspicuous hill forming the western extremity of a bed of metamorphic grit (or quartzite) and conglomerate, dipping at angles averaging about 50 degrees to the north-east; the quartzite rests upon greenstone schist, and has been affected by the same foliation which affects the latter. The quartzite is traversed by bands of laminated quartz of the type prevailing in the district. Most of the pebbles in the conglomerate are flattened out almost beyond recognition, though in some places they are well shown on the weathered surface of the rock.

Among the quartz schists which form the summit of what may be called the main range of Warrawoona is a bed which here and there contains what at first glance appears to be fossil wood [5766]. A characteristic specimen of this silicified wood (?) has a length of about $4\frac{1}{4}$ inches; cross sections of it are ellipsoidal in shape, the major axis being about three-quarters, and the minor axis about five-eighths of an inch in length. Microscopical sections both transverse and longitudinal were prepared, and were submitted

along with the specimen to Mr. Etheridge of the Australian Museum, Sydney, who was unable to detect any trace of organic structure in them. It is, however, quite possible that the dynamic metamorphism which these rocks have undergone may have entirely obliterated all traces of organic structure, and that some form of plant life existed at the time these beds were deposited.

Adjoining Lease 479, the Juneau, is a schist forming part of the main series which presents many points of interest.

In hand specimens the rock [5787] is of a very light brownish colour, and is distinctly foliated. In addition to quartz, which forms no inconsiderable portion of the rock, there are numerous elongated crystals of a clear glassy mineral, the cleavage faces of which are very distinctly marked, and which give a distinctive character to the rock. Under the microscope the rock is found to be made up of clear and unaltered fragments of felspar, very few of which however are twinned, quartz polarising in brilliant colours, a little colourless mica and a reddish brown substance, which may result from the alteration of some mineral rich in iron. The rock is clearly a felspathic schist, the field relations of which point to its being of clastic origin.

The greenstone schists and other allied rocks of Warrawoona occupy a large area of country, and vary very much in the width of their outcrop. It is of course possible that this may in part be due to differences in the folding (?). A feature in the physical structure of the greenstone schists which may have some significance is what may be called an anticline of foliation, the centre of which trends generally in the same direction as the main structural lines of the district. This is well exposed at a point a little distance to the south of the Gauntlet No. 3 North-West Lease.

A very important feature of these greenstone schists is the presence among them of unfoliated basic rocks, which sometimes occur in the form of lenticular belts of (in certain places) considerable horizontal extent. Several excellent sections in the district show these basic rocks passing by scarcely perceptible gradations into the greenstone schists.

It is possible that as the strike of these belts of massive basic rocks more or less coincide with that of the general foliation of the district, they may occasionally be mistaken for some of the older basic dykes, which have a parallel strike.

In one or two localities are belts of magnetic-schist, in the centre of some of which are uncrushed "eyes" (of large dimensions) of greenstone occurring in such a way as to indicate that the margins only of the mass have been crushed down into schist. Many of these schists contain very large quantities of magnetite, such as give a very distinctive character to the rock.

The foliated or sheared greenstones on the Gauntlet Lease contain large brown crystals [5767], a combination of cube and octahedron of iron ore, viz., limonite pseudomorphs after pyrites.

Many of these crystals are about an inch in length. In other portions of the field, the surface of the unfoliated greenstone is strewn with similar limonite crystals. Some of the greenstones are very much decomposed, and some of the constituent minerals are largely replaced by carbonates, giving the rock a very characteristic weathered surface at first sight, very suggestive of the weathered surface of some limestone.

The chemical composition of several of these greenstones and their allies is given in the table of analyses, page 66.

In mineralogical constitution the rocks present very many points of similarity.

The country rock [**5755**] of the Golden Gate Reef is a soft green talcose-chloritic schist, the chemical composition of which is shown in the table on page 66. The crystals of talc which are often of considerable length, have been as may be seen under the microscope, broken and torn apart by the stresses and strains to which the rock has been subject. The exact relation of this schist to the surrounding greenstone cannot be precisely determined, as access to the underground workings of the mine was not obtainable.

The rock [**5777**] which forms the matrix of the Imperialist Reef is a fine-grained talc-chlorite schist, identical with that of the Golden Gate. The analyses of the two rocks present also many points of similarity.

The Tom Thumb Reef is enclosed in a fine-grained chlorite schist [**5756**] which, when examined under the microscope, is found to be made up of quartz, felspar, chlorite, and epidote (?). The chemical composition of this rock is given in the table on page 66.

The country rock [**5768**] forming the matrix of the May-be reef is of a somewhat similar character, and, as its field relations indicate, owes its origin to the compression of a massive greenstone. Its mineralogical constitution does not appear to differ in any very essential feature from the other schistose greenstones; its chemical composition is given in the table quoted above.

The Gauntlet Lease is traversed by a band of chlorite schist [**5779**] in many respects identical with that forming the Tom Thumb Reef. The chemical composition of this rock agrees very closely with some of the massive diabases of other portions of the field.

At a point about 10 or 12 chains to the north-east of G.M. Leases 531 and 593 is a lenticular mass of a serpentinous rock [**5757**], the chemical composition of which is set forth in the table of analyses on page 66. The mass has a length of about 20 and a maximum width of about five chains, whilst its longer axis is in a direction of north-west and south-east, parallel to the main structural features of the district.

A very large quartz reef outcrops in the centre of the mass, but does not extend into the surrounding rocks. The serpentine is enclosed in the mass of acidic rocks, but in such a condition that its original condition is not quite clear; there seem, however,

grounds for believing it to have been brought into its present position by a fault.

The massive greenstones vary very much in grain; they all contain more or less hornblende (sometimes fibrous) and its alteration product chlorite, quartz, felspar, and calcite, together with an iron ore. Some, however, are very calcareous, and effervesce briskly on the application of acid.

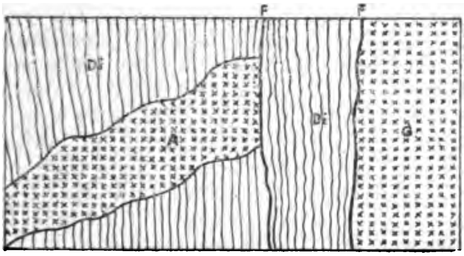
Detailed petrographical examination of all these rocks has not yet been made, but it is hoped to approach this subject at a later date, as opportunity offers.

Granite and allied Granitic Rocks.

The granite, which is of the normal type, occupies a rudely triangular patch on the southern boundary of the map, about 200 chains in length and about 40 chains in maximum width. It, however, extends for many miles far beyond the limits of the map. There seems good reason for believing that the granite is intrusive into the greenstone schists, though its northern boundary, to the south of the Imperialist Reef, is marked by a fault.

The exposure on the hillside, a plan of which forms Fig. 5, reveals the relationship of the granite and greenstone schists to each other.

FIG. 5.



PLAN SHEWING THE FAULTED NATURE OF THE GRANITE JUNCTION STH OF THE IMPERIALIST GOLD MINE. WARRAWOONA PILBARA G.F.
G. GRANITE A APLITE Di GREENSTONE SCHIST F FAULTS

In this section the greenstone schists abut sharply against a smooth wall of granite, which is inclined at an angle of from 45 to 55 degrees to the north, this angle being practically coincident with the dip of the foliation planes of the schists. A few inches of schist separate an aplite dyke of four feet in thickness from the main granite mass. The dyke traverses the schists in a direction almost at right angles to their general strike. A quartz reef occurs along the faulted junction some distance east of this point, in close proximity to the newer greenstone dykes, which traverse the centre of the field. There is no very clear evidence of a marked banding or foliation in the granite anywhere in the southern portion of the district. In that large granite mass on the north, just outside the limits of the map, it possesses a rude foliation or

banding, which is parallel to the general strike of the foliation of the schists forming the higher ground to the south.

Whether this banding has any connection with the general foliation of the district, or is an original feature of the granitic magma, has not been satisfactorily determined. If this banding in the granite is not an original feature, then it would seem to indicate that both it and the Warrawoona beds were subject to the same set of stresses and strains which were set up in the interval separating the beds of the Nullagine from the older series.

The north-east angle of the map is made up of felspar-porphyry [5792] sometimes occurring in the form of dykes. The rock, when a freshly broken and unweathered surface is examined, is found to be of a grey colour, with numerous crystals and fragments of a cloudy white felspar (some of which show twinning) set in a fine-grained matrix.

Examined under the microscope, the rock is found to be made up of a micro-crystalline ground mass of quartz, together with a small proportion of orthoclase, in which are embedded large crystals and fragments of felspar but no quartz. A relatively large quantity of biotite of a brownish colour occurs in many cases, arranged in bands which sweep round the porphyritic felspar in a manner paralleled by the flow structure developed in some volcanic rocks. The brown colour of the mica often passes gradually into a bright green, the result, probably, of alteration. The porphyritically developed felspar has not been optically determined, but the characteristic cross-hatched twinning in some parts would point to its being an orthoclase. The relatively large proportions of lime and soda as disclosed by the analysis [5792] shown in the table on page 66, would seem, on the other hand, to indicate that the felspar belongs to the lime-soda series. This felspar-porphyry is practically identical in its character with the Duffer's Creek porphyry referred to in the analysis [5392] of the rocks from Pilbara, on page 12 of Bulletin No. 15. There are few if any large porphyritically developed felspars in this latter rock, which perhaps may be held accountable for the smaller percentage of potash and lime, as shown in the analysis; in all other respects the two rocks are identical.

There does not seem, so far, to be any intimate relationship subsisting between this porphyry and the main granite mass, as developed on either side of the main axis of Warrawoona. The fact that it shows no signs of even a quasi-foliation, which characterises some portions of the granite, would seem to indicate that the porphyry is of later date than the granite. It may, perhaps, have some connection with the volcanic activity which prevailed during the period of the deposition of the Nullagine Series.

The geological age of the granite cannot, as yet, be exactly determined; it is, certainly, newer than the Warrawoona Beds, into which it is intrusive. The granite passes beneath the Nullagine

Series, which the evidence* so far available seems to point to being of Cambrian Age; in this case the granite would be Pre-Cambrian.

Basic Dykes.

The basic dykes of Warrawoona belong to two different periods; the district, however, furnishes no satisfactory evidence as to the exact age of each set.

The newer basic dykes traverse the whole width of the field in a general north-east and south-west direction, and extend for very many miles to the north and south of the country examined. The system of newer dykes intersects the auriferous belt between the Bow Bells and the Gauntlet groups of reefs almost at right angles to the general trend of the series. In no case do these dykes attain any great thickness, and their breadth varies greatly in different parts; the thickness, as shown on the Geological Map of Warrawoona (Plate III.), has been somewhat exaggerated, in consequence of the small scale employed. Such few cross sections as may be seen of them indicate that they approach very closely to the vertical.

The rocks of which they are composed are basic compounds, an analysis of the most typical [5773] is shown in the table on page 66.

In hand specimens these dyke rocks vary from coarse to medium grain, and are seen to consist of a greenish grey felspar, together with a ferro-magnesian constituent and an iron ore. Under the microscope the rock is found to consist of allotriomorphic crystals of a plagioclastic felspar, many of which present that turbid mealy aspect so characteristic of alteration, together with brown or almost colourless augite, and a little enstatite (?) passing into bastite (?). The place of some of the augite is taken by a pale green fibrous decomposition product which may be chlorite. The iron ore, which is often represented by skeleton crystals, is probably ilmenite. The rock is therefore a diabase.

The regular continuity of the system of dykes has been interrupted in the vicinity of their intersection with the auriferous series. From the position in which this interruption occurs, it would seem that these newer dyke rocks had undergone considerable movement since their injection. The somewhat curved and distorted fragments or isolated patches all point to a series of later movements along lines parallel to that of the main trend of the auriferous belt of Warrawoona.

The older series of dykes have a general trend approximately at right angles to that of those previously described, and are in some cases intersected by them. Like the newer dykes they are all basic compounds. In some cases they have been crushed and sheared into a schistose greenstone, which occasionally takes the form of a schist which has a characteristic weathered outcrop, very suggestive of a calcareous schist. These sheared dykes are all indicated upon the map.

* Supra, p. 27.

Table of Analyses of Rocks from Warrawoona.

By E. S. Simpson.

Geological Museum No.	5755	5756	5757	5765	5768	5773	5777	5778	5779	5780	5781	5792	5793
Specific Gravity	2·94	2·88	2·91	2·76	2·79	3·00	2·93	2·82	2·62	2·84	2·58	2·73	3·07
Silica, SiO_2	43·25	43·47	30·63	17·63	41·88	50·48	43·90	45·68	55·00	48·54	65·75	69·14	50·20
Alumina, Al_2O_3	9·98	14·87	1·68	4·28	10·13	23·18	9·13	8·94	24·30	13·67	19·39	14·71	17·95
Ferric Oxide, Fe_2O_3	1·93	3·35	5·94	1·97	*Nil*	3·07	1·20	2·23	3·93	2·13	·51	3·47	9·49
Ferrous Oxide, FeO	10·04	14·93	4·72	*Nil*	9·59	8·86	10·48	5·91	7·53	10·04	8·05	·78	4·20
Magnesia, MgO	22·48	12·64	32·30	14·74	7·20	·64	19·17	12·25	2·30	4·54	2·36	1·09	2·26
Lime, CaO	5·31	1·18	Trace	24·63	13·06	7·47	7·46	12·56	·18	6·46	*Nil*	4·83	7·76
Soda, Na_2O	·49	·55	·41	·92	1·30	2·17	·57	1·82	2·43	3·58	·98	4·24	1·01
Potash, K_2O	Trace	·13	·11	·43	·10	·83	·09	·12	Trace	·04	4·66	1·00	·14
Combined Water, H_2O	4·74	6·82	·52	·70	3·51	1·71	4·68	1·92	3·14	2·74	1·78	·08	3·04
Hygroscopic Water, H_2O ...	·20	·26	·15	·05	·07	·10	·04	·07	·27	·04	·10	·04	·10
Carbonic Anhydride, CO_2 ...	·17	*Nil*	23·03	34·94	11·60	·55	2·46	8·34	·98	7·14	·16	·40	1·12
Titanic Oxide, TiO_2	·50	1·48	·52	·20	1·15	·38	·30	·40	Trace	1·12	·66	·30	1·42
Pyrites, FeS_2 { Fe	·03	·05	·09	*Nil*	·16	·14	·02	·04	Trace	·12	·11	Trace	·14
Pyrites, FeS_2 { S	·04	·06	·11	*Nil*	·18	·16	·03	·05	...	·14	·12	...	·16
Manganese Protoxide, MnO ...	·54	·10	·11	Trace	·32	Trace	·05	·09	Trace	Trace	*Nil*	·21	·37
Total	99·70	99·89	100·32	100·49	100·25	99·74	99·58	100·42	100·06	100·30	99·58	100·29	99·36

5755.—Talc-chlorite schist. Golden Gate Lease, Warrawoona, Pilbara Goldfield. Analyst, E. S. Simpson.

5756.—Chlorite schist. Tom Thumb Lease, Warrawoona, Pilbara Goldfield. Analyst, E. S. Simpson.

5757.—Serpentine schist. Near Moolyella Gap, Warrawoona, Pilbara Goldfield. Analyst, E. S. Simpson.

5765.—Carbonated schist. Near Ironclad Battery, Warrawoona, Pilbara Goldfield. Analyst, E. S. Simpson.

5768.—Chlorite schist. May-be Lease, Warrawoona, Pilbara Goldfield. Analyst, E. S. Simpson.

5773.—Newer Diabase Dyke. Warrawoona, Pilbara Goldfield. Analyst, E. S. Simpson.

5777.—Talc-chlorite schist. Imperialist Lease, Pilbara Goldfield. Analyst, E. S. Simpson.

5778.—Older Greenstone Dyke. Warrawoona, Pilbara Goldfield. Analyst, E. S. Simpson.

5779.—Foliated Greenstone. Gauntlet Lease, Warrawoona, Pilbara Goldfield. Analyst, E. S. Simpson.

5780.—Greenstone. Bow Bells Lease, Warrawoona, Pilbara Goldfield. Analyst, E. S. Simpson.

5781.—Schist. Bow Bells Lease, Warrawoona, Pilbara Goldfield. Analyst, E. S. Simpson.

5792.—Felspar-Porphyry. North side of Main Range, Warrawoona, Pilbara Goldfield. Analyst, E. S. Simpson.

5793.—Greenstone. Warrawoona, Pilbara Goldfield. Analyst, E. S. Simpson.

Fissures, Faults, etc.

A very marked feature in the structure of Warrawoona is the occurrence of those bands of laminated quartz which traverse the whole length of the field, these being locally spoken of as "dykes."

These bands often rise in the form of rough serrated ridges, which, by virtue of their power of resisting denuding agencies, stand out in bold relief, and can be followed across country for, in some cases, miles. They are, wherever seen in section, either vertical or inclined at high angles to the north east. In the case of the crosscut from the south drive in the tunnel workings of the Bow Bells Mine (Plate IV.), a dip of 65 degrees was observed. Although this vein, as seen underground, proved to be ten feet in thickness, there did not appear to be any distinct line of demarkation between it and the country rock, the whole section in the crosscut suggesting a gradual replacement of the original rock along lines of maximum compression or foliation.

Similar cases of a gradual transition between the quartz and the country rock can be noticed in several cases along the summits of the ridges in the district.

Of these bands there are twelve in all, the most conspicuous and the most important being that which traverses the whole line of

leases across the field in a north-westerly direction. This particular vein is locally spoken of as "The Dyke," and it may be that it represents an old line of weakness along which disturbance has taken place at several distinct periods.

The other veins, it will be noticed, all taper off gradually along a line which is, approximately, parallel to the dyke, and are disposed somewhat in the shape of a fan, the ribs of which open out gradually to the west.

The mode of occurrence and ending off of these quartz veins is very suggestive of this line being a fault; to which the interruption in the continuity of the newer diabase dykes in the vicinity would seem to lend additional colour. There is, however, no sign of any such fault on the surface, and, in fact, owing to the nature of the surrounding rocks, any such might readily escape detection.

These laminated quartz veins have been subject to a certain amount of faulting, and all those which have any effective throw have been laid down upon the map. As all the veins have a very high underlie, a considerable vertical displacement might easily take place without having any very marked effect upon the outcrop.

When examined under the microscope, typical specimens of these laminated quartz veins [**5758, 5759**] present no features of any particular moment.

In addition to the laminated quartz veins previously mentioned, there is another type of fracture developed on the field, which makes itself manifest in two well defined bands, trending approximately parallel to them. These bands, which form a very pronounced feature in the landscape, are represented by a "sheeting" or "zoning" of the country rock, the width of which varies within very wide limits. The photographs "F" and "G," taken by the late Mr. S. J. Becher, give a graphic idea of the nature of these zones, which in reality result from the powerful compression to which the rocks have been subjected. There are, occurring in these bands, more or less extensive lenticules or "eyes" of quartz, parallel to the foliation; and many of these quartzes have a characteristic and distinct greenish hue [**5759**]. Fig. 6 shows a section across one of these compression fractures, with the characteristic quartz lenses, traversed by a reef of much newer formation. This newer reef is from 12 to 14 inches in thickness. The country rock traversed by this fracture has been silicified along the lines of compression, whilst the vertical slickensided faces indicate subsequent movement, which, however, may not have been very great. One of these bands of compression or shearing traverses the whole length of the Klondyke Boulder Lease (Plate VI.), parallel to the reef of the "Leader" type; it forms a very marked feature on the surface and stands out in bold relief. The foliæ, however, are not, in this section, vertical, but inclined at a very high angle to the north-east.

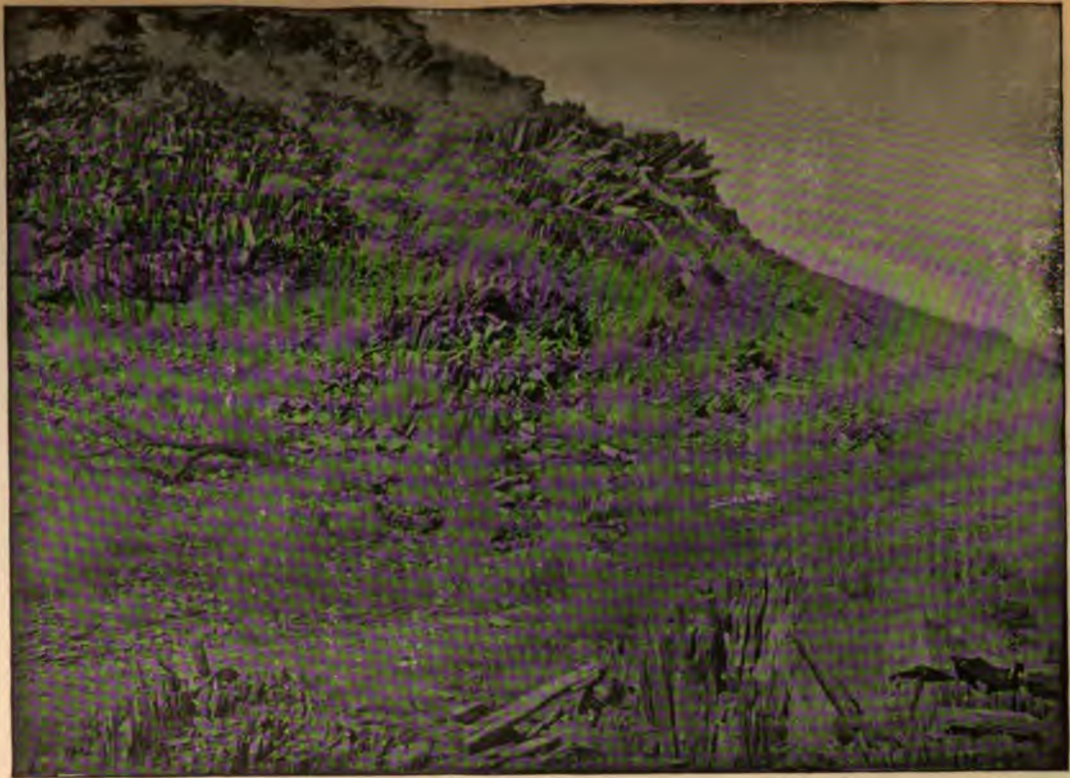


PHOTO.: S. J. BECHER.

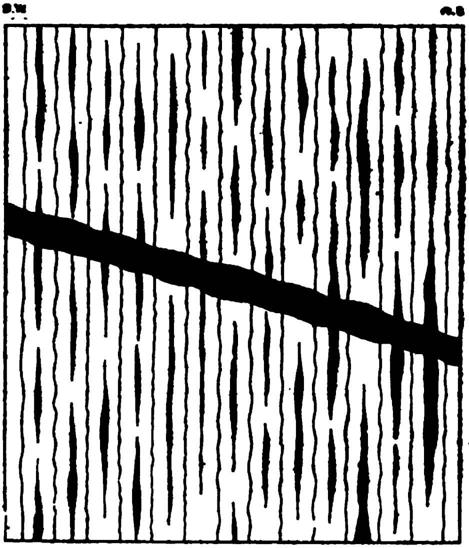
Sheeted Zone in country rock, Warrawoona, Pilbara Goldfield.

PHOTO.: S. J. BECHER.

Enlarged view of Sheeted Zone in country rock, Warrawoona, Pilbara Goldfield.

The faults which many of the reefs have undergone are referred to below under the heading of the Auriferous Deposits, and the position of those which can be actually observed and those the

FIG. 6.



SECTION ACROSS A COMPRESSION FRACTURE TRAVERSED BY A QUARTZ REEF. WARRAWOONA
PILBARA G.F

existence of which is inferred are shown upon the mining plans which form Plates IV., V., and VI.

Economic Geology.

Auriferous Deposits.

The auriferous deposits of Warrawoona are quartz reefs, which outcrop over a belt about six miles in length and about 20 chains in width.

There are no alluvial deposits of any extent anywhere within the limits of the area examined.

In addition to what may be called the main belt of Warrawoona, there are several minor outlying virtually isolated reefs, which have been worked in a more or less desultory fashion.

The position of all the quartz reefs has been laid down upon the Geological Map of Warrawoona (Plate III.) with such a degree of accuracy as the scale employed and a plane table survey would permit. No considerable body of ore, which is obvious to anyone making a fair and reasonable inspection of the surface, has been overlooked. The reefs exhibit, when viewed on the whole, a general

parallelism to the trend of the main structural features of the district. A careful examination of all the reefs, both on the surface and below ground, wherever such was possible, showed that they could be divided into two totally different types, which are sharply differentiated from each other.

The first type may, for convenience, be called the Normal or Fissure Vein Type, whilst the "Kidney" shaped lenticular quartz reefs of the second are locally spoken of as the "Leader."

Both types have been more or less opened up, and their relative importance as gold producers well established, as may be seen by a reference to the tables below.

Tables showing the yield of—

(*a.*) The Normal Quartz Reefs, and

(*b.*) The Leader Type of Deposits of Warrawoona.

The Normal Quartz Reefs.

Year.	Ore crushed.	Gold therefrom.	Rate per ton.
	tons.	ozs.	ozs.
1898	626·85	3,143·72	5·01
1899	1,194·75	3,679·56	3·08
1900	1,854·31	4,978·74	2·68
1901	355·75	874·25	2·45
1902	396·55	774·80	1·95
1903	429·85	1,080·64	2·51
1904	105·45	236·44	2·24
Total	**4,963·51**	**14,763·15**	**2·97**

The Leader Type of Deposit.

Year.	Ore crushed.	Gold therefrom.	Rate per ton.
	tons.	ozs.	ozs.
1898	78·55	276·75	3·52
1899	167·10	470·62	2·81
1900	87·40	314·45	3·59
1901	46·25	126·60	2·73
1902	49·70	147·26	2·96
1903	71·50	166·25	2·32
1904	49·00	125·38	2·55
Total	**549·50**	**1,627·31**	**2·94**

The data embodied in these two tables have been drawn up from the official statistics, but, of course, could not have been tabulated without a personal examination of the different reefs in the district. The figures demonstrate conclusively that whilst the

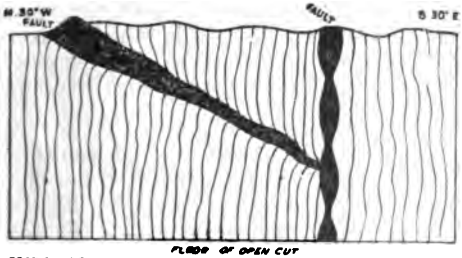
average value of the two types of deposit is about equal, it is, however, the normal quartz reefs that have, up to the present, been most extensively worked, and the reason is not far to seek.

The reefs of the Leader type are in every respect identical with those described * as forming the important deposits in the mining centre of Edjudina.

At Warrawoona, the "Leader," which forms a continuous band, so far as prospecting operations have shown, of about two and a half miles in length, occurs along a line of rupture, which is forcibly shown by the powerful slickensided surfaces exhibited almost everywhere underground. These faces are often coated with fine films of gold. The "reef" is represented by "kidney" or damper-shaped lenses of quartz which vary from a few inches in width to a foot or two in length along the vein. The interval between each lens of quartz naturally fluctuates within very wide limits. Sections are visible in some of the workings fully described on a later page, which show the "casing" of the lens to be quartz of a somewhat different type; cases of this kind, which are of frequent occurrence along the "Leader" line, seem to point to the quartz lenses being portions of a pre-existing quartz reef which has been shifted in segments, as it were, along a vertical line of dislocation. Until these quartzes have been submitted to microscopical examination it is impossible to determine whether they exhibit optically any signs of mechanical strain, as would be naturally expected.

There seem very strong grounds for believing that the reefs of the "Leader" type are of later formation than those of the true fissure veins. Fig. 7 shows a section of a fissure vein abruptly cut off by the "Leader."

Fig. 7.



SECTION OF THE REEFS IN THE OPEN CUT NEAR THE SOUTH EASTERN BOUNDARY OF G.M.L 308 WARRAWOONA PILBARA G.F.

From the very nature of the Leader it is naturally somewhat difficult to work, as the stopes must be kept within the narrowest possible limits, and merely the auriferous quartz lenses extracted.

* Notes on the country between Edjudina and Yundamindera, by A. Gibb Maitland, Bulletin 11. Perth: By Authority, 1903, pp. 14, et seq.

A feature of many of the normal reefs, notably those on the Bow Bells lease, is the folding which they have undergone; this characteristic is particularly well exemplified in the case of the Horseshoe vein, and is shown on the plan which forms Plate IV. It will be noticed that in those cases in which the folding has taken place, there is almost invariably a relatively large pocket of ore at the apex of the arch. The fold in the Horseshoe vein of the Bow Bells lease merely differs from the saddle reefs as depicted in many geological manuals in the fact that in this particular case the legs are horizontal. Mining operations, however, have hardly been carried sufficiently far to determine whether or not the apices of the folds contain any higher grade ore than what may be called the legs of the reef. The fact that rich chutes are known to prevail in intimate connection with the apices of the folds in other mining districts where the quartz reefs have been violently contorted is a circumstance which should commend itself to the attention of those engaged in the exploitation of the reefs in question. All the evidence available points to the fact that the folding of the reefs is the result of great lateral pressure acting upon the country rock after the formation of the reefs themselves. The folding and puckering of some of the quartz veins is well illustrated, even in many hand specimens, notably in the quartz schist [5789] on the Gauntlet East, G.M.L. 560, a micro-photograph of which forms Fig. b. Photograph "H." This lateral pressure has not only folded but has faulted many of the reefs. Wherever possible the faults which have any effective throw have been mapped and shown in both the geological and mining plans as well as in some cases in the sections by which they are accompanied. The high inclination of the majority of the veins is such as of course might permit of a considerable displacement without any marked effect upon the outcrop, hence many faults, unless disclosed during the course of mining operations, might easily escape detection. In the case of the main reef on the Gauntlet lease, the rich shoot for which the mine is famed is coterminous with the fault which traverses the whole breadth of the lease. It is, however, not yet clear whether this fault fissure formed the channel along which the mineralising solutions percolated.

In addition to these normal vertical faults, there are also reverse faults at thrust planes, which are either horizontal or are inclined at a very low angle to the horizon. Typical instances of these are to be found in the workings on the Gauntlet and the Klondyke-Boulder leases; in the first of these cases the actual horizontal displacement measures only a few inches.

The reefs of both types are composed of a hard, translucent and crystalline quartz, which, in addition to the gold, contains in subordinate quantities pyrites, chalcopyrite, limonite, malachite, ferruginous wad, and a muscovite mica which is partly chromiferous.

In some cases the gold can be seen contained in cavities, evidently left by the oxidation of pyrites.

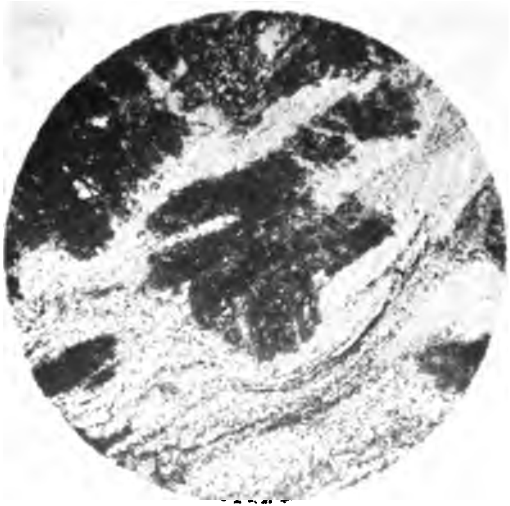


PHOTO.: E. S. SIMPSON.
Broken Crystals of Felspar (?) in sheared Felspar-Porphyry [5788], Warrawoona. Enlargement, 11 diameters.

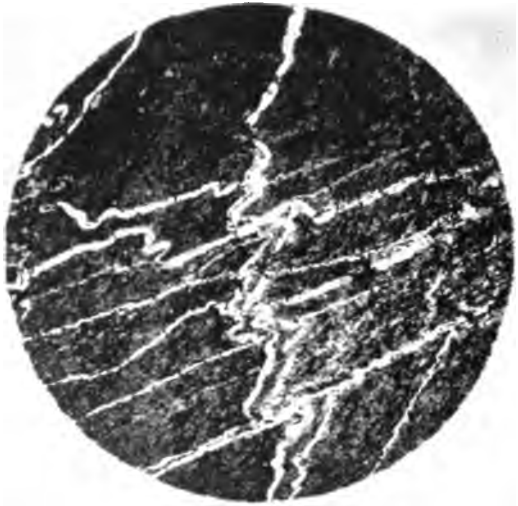


PHOTO.: E. S. SIMPSON.
Section of Quartz Schist [5789] showing contorted quartz laminæ in relation to stratification and cleavage foliation, G.M.L. 560, Warrawoona. Enlargement, 11 diameters.

Cases have been observed of the occurrence of calcite [5776] carrying a trace of gold; possibly the parent source of the calcite is to be looked for in the lime-soda felspars which enter into the composition of the greenstone and its allies, the country rock of many of the quartz reefs.

Although the total gold yield of Warrawoona has been 17,294·18ozs., recovered from the milling of 5,700·01 tons of ore, thus giving an average value of 3·03ozs. per ton, and many of the reefs have been opened up, these, however, have only been worked to very shallow depths.

All the mines which were open to inspection were visited, and full descriptions of them are given in the following pages. In the case of three properties—the Gauntlet, the Bow Bells, and the Klondyke Boulder, the reefs on which are instructive examples of the normal type as developed on the field—detailed surveys on a large scale of the various ore bodies, faults, etc., were made in the hope that they might in some measure furnish a guide as to the general behaviour of the reefs of this class in the locality. The result of these surveys has been embodied upon plans on the scale of 100 feet per inch accompanying the report, Plates IV., V., and VI.

For convenience of description, the mines and other workings are described in geographical sequence, commencing at the north-westernmost end of the field.

The Mines.

Princept, G.M.L. 517.—This is the most north-westerly lease on the Warrawoona Belt. The ground is now abandoned, and so far as may be seen very little work has been done upon the property. The surface of the lease is occupied by greenstone-schist of the prevailing type.

Near the north-western boundary of the lease is a shaft of unknown depth, sunk upon a vertical reef of about 12 inches in thickness. The reef has a general north-eastern and south-western strike. So far as may be judged by the stone lying at grass the quartz [5754] contains oxide of iron, green carbonate of copper, carbonate of iron, together with a little red copper oxide. An assay of a characteristic sample [5754] of the ore yielded in the Survey Laboratory gold at the rate of 1dwt. 15grs. per ton.

In addition to this there are two other reefs on the property, situated near the south-eastern boundary, and lying about 300 feet apart. The westernmost and most conspicuous of these forms the summit of a very prominent rise on the ground, and, as measured at the top, is from 20 to 25 feet in thickness. So far as may be seen the reef is vertical, and strikes a little to the west of north. About three feet to the west of this is a parallel reef of ice-like quartz, but of no horizontal extent. The eastern reef, about 300 feet distant, extends some considerable distance southwards, beyond the confines of the property.

The following table gives the yield of this property. The gold was entirely derived from the reef in shaft above mentioned:—

Table showing the Yield of the Princept Reef.

Year.	Ore crushed.	Gold therefrom.	Rate. per ton.
	tons.	ozs.	ozs.
1899	2·15	5·00	2·32

Cutty Sark, G.M.L. 521.—Messrs. Skogsberg and Svensen. This property is an old lease, the Cutty Sark, which has been resurveyed, and part of it is now held as Q.C. 142. The reef worked on this lease has an average strike of 305 degrees, and appears to be the same as that which enters the property near the north-east angle of the lease.

A vertical shaft 74 feet in depth has been sunk by the present holders of the property, and the stone stoped out from a depth of 60 feet; the reef is said to have been four feet in thickness. From the bottom of the shaft crosscuts six feet in length have been put in east and west respectively. Owing to the state of the country rock it is stated that work had to be abandoned at this level. At the date this property was visited, access could not be obtained below 33 feet from the surface; at this depth is a large body of quartz five to six feet thick, it is however merely a somewhat larger bulge on the reef than usual.

There are about 18 to 20 tons of quartz raised and awaiting crushing. The quartz at grass shows gold freely, it contains the red oxide, and the blue and green carbonates of copper in relatively small quantities, in addition to a little galena.

The only crushings from this reef were recorded in 1898 and 1904.

Table showing the Yield of the Cutty Sark Reef.

Year.	Ore crushed.	Gold therefrom.	Rate per ton.
	tons.	ozs.	ozs.
1898	4·75	10·10	2·12
1904	31·30	49·00	1·56
Total	36·05	59·10	1·64

Tom Thumb, Q.C. 128 (141).—Trangmar. This property was originally embraced within the boundaries of G.M.L. 519, the Carnoustie.

A good deal of work must have been done upon this property by the previous owners of the ground, but most of these workings are inaccessible at the present time.

A vertical shaft 94 feet in depth has been sunk through almost vertical beds of chlorite schist [5756].

At 65 feet is a level, which has been put in along the strike of the country for a distance of 40 feet to the west. The face of the drive connects with the old workings, the end of the rich chute being at this point, and the stone, merely thin lenticular veins along the foliæ, being stoped out to the surface from the westernmost old shaft.

The quartz lenticules, of a totally different type to those occurring in Kopcke's leader, are said to attain a thickness of 12 inches in places. At the foot of the main shaft a quartz reef was met with and a fairly large body of water was encountered, at the point at which the stone was first intersected. The water is standing in the shaft at 85 feet from the surface. From stone shown to me, it appears that the quartz lenticules must be very rich in places.

Table showing the Yield of the Tom Thumb Reef.

Year.	Ore crushed.	Gold therefrom.	Rate per ton.
	tons.	ozs.	ozs.
1903*	34·40	155·57	4·52
1904	2·15	9·09	4·22
Total	36·55	164·66	4·50

*Previous to 1903 the yield was included under the heading of Sundry Claims. In 1898, however, the official statistics show that 45·40 tons of ore crushed from the Carnoustie reef yielded 178·11ozs., or at the rate of 3·92ozs. per ton. This, however, in all probability was obtained from the reef outcropping just outside the north-east angle of the claim, as shown in the Geological Sketch Map of Warrawoona.

Golden Gate, G.M.L. 607 (now Q.C. 137).—The unsurveyed quartz claim, 137, originally embraced by the Golden Gate Lease, G.M.L. 607, lies some little distance to the south of the Tom Thumb. The workings, however, are inaccessible; the main shaft is reputed to have reached a depth of 76 feet, and the reef stated to have consisted of lenticular quartz veins occurring along the planes of foliation of the talc-chlorite schist [5755].

Table showing the Yield of the Golden Gate Reef.

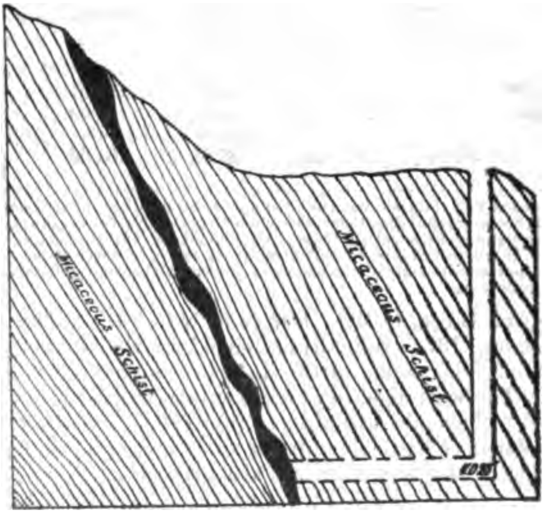
Year.	Ore crushed.	Gold therefrom.	Rate per ton.
	tons.	ozs.	ozs.
1901	6·00	16·40 *6·00	2·73
1902	13·00	29·10	2·24
1903	40·45	73·00	1·80
Total	59·45	118·50 *6·00	1·99

* Dollied and Specimens.

Seven Dials, G.M.L. 605.—The Seven Dials property, now abandoned, lies at the north-western extremity of what may be called the Bow Bells-Gauntlet Zone, as may be seen by an inspection of the Geological Sketch Map of Warrawoona. (Plate III.)

The reef prospected enters the property near the north-western boundary, and, after a somewhat sinuous course, leaves it by the south-eastern boundary, not far from the north-east angle of the lease. So far as may be seen in an opencut on the surface, the reef underlays to the north-east at 65 degrees, and varies from two to three feet in thickness. The reef appears to be somewhat faulted along the outcrop, though the horizontal displacement is not more than three or four feet in each case. A vertical shaft (Fig. 8), 28 feet in depth, has been sunk at a point 34 feet north-east from the outcrop. The shaft has been carried down through a narrow belt of a fine micaceous schist.

Fig. 8.



SECTION ACROSS THE SEVEN DIALS REEF G.M.L.605 WARRAWOONA PILBARA G.F

Chance, G.M.L. 534.—This lease, now abandoned, occurs a few feet to the north-west of G.M.L. 531.

Work has been concentrated upon a somewhat similar deposit to that occurring in G.M.L. 531. At the outcrop the section across the vein from west to east is as follows:—Quartz, six inches; formation, eight inches; quartz, 12 inches; formation, 12 inches; quartz, three feet six inches. An underlay shaft has been put down to an unknown depth, but being inaccessible, no particulars as to the nature and behaviour of the reef underground are available.

The quartz [5769] is almost pure white, and contains oxide of iron, small quantities of green carbonate of copper, and chalcedony.

Lying in the vacant triangular piece of ground between this lease and G.M.L. 531 is an underlay shaft, which has been put down to an unknown depth, upon a thin vein of quartz underlying northwards. Workings along the outcrop further down the hill show the vein to attain a maximum thickness of 12 inches.

The returns of a small crushing in the year 1898 are shown in the table below.

Table showing the Yield of the Chance Reef.

Year.	Ore crushed.	Gold therefrom.	Rate per ton.
	tons.	ozs.	ozs.
1898	4·00	8·35	2·08

May-be, G.M.L. 531.—This lease is abandoned, and no work had evidently been done upon it for some considerable time past. As may be seen by an inspection of the geological sketch map, it will be noticed that the northern portion of the property is traversed by the main laminated quartz vein, which forms what may be called the backbone of Warrawoona; this quartz vein has been traversed by three faults which have had the effect of shifting the outcrop a few feet in each case. All the work on the lease centred on the quartz reefs occurring on the south side of the laminated quartz vein. On the summit of a hill near the south-west angle of the lease is an open cut, 20 feet in length, exposing about an inch of quartz encased in a banded (partly silicified) greenstone [5768], the foliation planes of which underlie at an angle of 60 degrees northerly. The quartz leader lies along a compression fracture, which from its geological position may represent the north-western extension of Kopcke's leader.

Bow Bells Block No. 1, G.M.L. 524.—This is an old abandoned lease adjoining G.M.L. 523 on the north-west; it embraces a narrow strip of the northern portion of Bow Bells No. 1 West (*q.v.*). A few tons of stone have been crushed from this lease in 1898, as shown in the table; it is probable that this stone was raised from the reef in the inaccessible vertical shaft, of which mention is made in the description of the reefs on G.M.L. 593.

Table showing the Yield of the Bow Bells Block No. 1 Reef.

Year.	Ore crushed.	Gold therefrom.	Rate per ton.
	tons.	ozs.	ozs.
1898	12·00	10·50	·87

Bow Bells No. 1 West, G.M.L. 593.—An abandoned 24-acre lease adjoining the Bow Bells on the north-west. As may be seen by an inspection of the geological map, there are seven quartz reefs traversing the lease in addition to the main laminated quartz vein. The principal work has been done upon a reef outcropping near the northern boundary of the lease. A vertical shaft, now filled up, had been put down to an unknown depth on the slope of the northern wall of the valley, traversing the ground, and connects with the surface lower down by a tunnel about 100 feet in length, driven on a bearing of 35 degrees. The face of the tunnel is filled with *débris* falling down the shaft, so that nothing whatever can be seen of the reef. The mouth of the vertical shaft shows a good solid body of quartz, varying from two to four feet in thickness. This stone in all probability represents the continuation of the large reef outcropping to the north of main shaft on the Bow Bells lease, distant about 400 feet. At the mouth of the tunnel is a heap of quartz [5770] showing free gold, in addition to muscovite, which is partly chromiferous and partly stained by limonite, iron pyrites, and chalcopyrite.

Another reef outcropping 18 feet north of the laminated quartz vein, forming the southern wall of the valley. The shaft is inaccessible, but as measured to the surface of the water at present standing in it, is at least 32 feet deep.

A little stone has been raised, and now lies at the mouth of the shaft. It contains [5771] muscovite, which is partly chromiferous, ferruginous wad, and limonite. The reef varies from one to three feet in thickness, and has such a strike as would carry it into the laminated quartz vein some distance to the west.

Bow Bells, G.M.L. 505.—The Bow Bells lease comprises an area of 12 acres, and was originally taken up by Messrs. Royer, Barnes, and Burroughs in the year 1898; it eventually passed into the hands of the present holders, The British Exploration Company of Australia, in 1901.

The lease, as may be seen by the Geological Sketch Map of Warrawoona, lies in the same zone as that which embraces the Gauntlet Mine, G.M.L. 483, from which it is distant about 100 chains to the north-west. The surface of the lease is occupied by greenstone schists and allied rocks, and the southern boundary of the property is traversed by the band of laminated quartz, which extends across the lease from end to end.

As shown by the large scale plan of the mine (Plate IV.), there are seven reefs upon the property.

The Northern Reef (No. 3 shaft), extends along the surface for a distance of about 80 feet, and underlies at a high angle to the north-east; the thickness of the reef as showing at the surface is

12 inches. The shaft by which the reef is worked is 39·63 feet above the level of the main (or Horseshoe) shaft, and has been carried down to a depth of 45 feet 9 inches. The shaft was inaccessible, but I was informed by the Manager (Mr. Hanemann) that at the bottom the reef proved to be small and poor. At a point about 50 feet north of the shaft, and along the outcrop of the same reef, is a shallow shaft, showing about 12 inches of quartz. No. 2 tunnel, 1·08 feet above the main shaft and 70 feet from it, was started with the object of intersecting the reef in No. 3 shaft, but after being carried in 8 or 10 feet, through country rock, it was apparently abandoned, and is now used as a store.

What may be called the *Horseshoe Reef* is worked from the main shaft, which has been sunk at the most convenient spot in the fork of the reef. The northernmost leg of the reef, as may be seen by the plan of the reefs (Plate IV.) can be followed for a distance of about 260 feet northwards, at which point it gradually tapers out to a thin vein of quartz, considerably less than an inch in thickness. At the bend of the horseshoe, the reef is about five feet in thickness. The southern leg of the reef can be followed, with a varying thickness, traversing No. 2 shaft, for a distance of about 150 feet, to a point at which it turns southerly, continuing on that course for a further distance of 50 feet, whence it gradually disappears. The main shaft, which has been carried down 106 feet 2 inches vertically, intersects the southern leg of the reef at No. 1 level, put in at a depth of 91 feet 6 inches; this reef is about three feet in thickness. The northern leg of the reef is represented by the 12 inches of quartz, intersected in the northern drive at a point about 40 feet from the shaft. An eastern drive about 50 feet in length has been put in practically along the country rock forming the footwall side of the reef. A narrow quartz vein, however, occupied the centre of the drive, and may possibly represent the small vein showing on the surface, for about 30 feet west from the mouth of No. 2 shaft. The eastern drive has been carried south on a bearing of 171 degrees for a distance of 18 feet, through massive greenstone. It is contemplated continuing this with the object of intersecting the rich chute worked in the reef in No. 1 shaft, and hauling all the stone to be milled from the main shaft.

The Tunnel Workings.—The workings at No. 1 tunnel and No. 1 shaft, are the most extensive, and appear to be the most important on the property. The mouth of the tunnel is 18·94 feet above the level of the main shaft, and has been carried in for a distance of 85 feet from the mouth to a point at which it intersects the reef, followed down from the surface in the workings from No. 1 shaft. Forty-five feet back from the face of the tunnel is a quartz reef two feet six inches in thickness, which in all probability represents the northern leg of the main reef. On the surface at the mouth of No. 1 shaft the two legs of the reef are 20 feet apart, whilst in the tunnel, 59 feet vertically below, they are 40 feet apart,

Twenty-three feet from the mouth of the tunnel is a small reef of six inches underlying to the north-east, and which in all probability represents the feather edge of the middle or lens-shaped mass of quartz (the Middle Reef) shown on the plan (Plate IV.) as lying midway between the Main and the Horseshoe Reefs. From the face of the tunnel, drives have been carried north and south for distances of 60 and 60 feet respectively; and for a length of 40 feet northwards from the face of the tunnel the reef has been stoped out to the surface, and has produced, up to the end of 1903, 483·70 tons of quartz, officially recorded as yielding 855·69ozs. of gold, or at the rate of 1·76ozs. per ton. The reef can be followed with more or less interruption northwards, but to the southwards it appears to be represented by a mere thread of quartz. At a point about 60 feet south from the tunnel a crosscut has been put in 40 feet south from the drive, through more or less foliated greenstone, with thin films and threads of quartz along the foliation planes. At the face of the crosscut the laminated quartz vein has been pierced and proved to be 10 feet in thickness, with an underlie of 65 degrees to the north-east. There does not seem to be any distinct line of demarcation between the country rock and the vein; the whole appearance suggesting a gradual replacement of the original rock along lines of maximum compression or foliation. On the footwall side of the vein is a body of quartz of as yet unknown thickness; in its general appearance, this quartz closely resembles some of the auriferous quartz of other portions of the field, and on that account seems worthy of being, at least, opened out and prospected. From the foot of the main shaft, and at the face of the tunnel, a winze, No. 1, has been carried down on the reef 77 feet 6 inches; this winze, which was inaccessible below 24 feet from the drive, has been put down on the footwall side of the chute followed above. No. 2 winze, however, about 20 feet to the north has been put down in the centre of the chute, and carried down 83 feet. The chute, which underlies north, leaves the winze at about 40 feet. The reef in this winze is very strong, and in places large, attaining as much as eight to 10 feet in thickness; at the foot of the winze, owing to a large bulge in the reef, its exact width had not been ascertained at the time of my visit. An intermediate level connects the two winzes at 24 feet six inches below the drive; about 200 tons of ore have been taken out above, and now await crushing. The quartz [5782] has a very ice-like appearance, and contains small scales of sericitic (?) mica, and irregular patches of serpentine. A sample of it assayed gold at the rate 1dwt. per ton. It is contemplated intersecting this chute from No. 1 level in the main (Horseshoe) shaft by a crosscut put in from the face of the eastern drive, as may be seen in the section (Plate IV.). The width of the chute appears to be about 35 or 40 feet.

There are many points of similarity between the geology and economic features of this property and the Gauntlet. The ore deposits in each case belong to one and the same type, and both occur in the same mineral zone.

So far as may be seen by a careful inspection of the surface it appears as though a considerable amount of faulting has gone on. The inferred position of these faults has been indicated upon the plan which forms Plate IV.

The following table gives the yield of the reefs on this property:—

Table showing the Yield of the Bow Bells Reefs.

Year.	Ore crushed.	Gold therefrom.	Rate per ton.
	tons.	ozs.	ozs.
1898	55·00	152·40	2·77
1899	183·00	342·30	1·87
1900	104·20	175·29	1·68
1901	*Nil*	*Nil*	...
1902	141·50	185·70	1·31
1903	*Nil*	*Nil*	...
1904	*Nil*	*Nil*	...
Total	483·70	855·69	1·76

Adjoining the Bow Bells Lease on the north, and on the ground taken up for a battery site, is another very conspicuous quartz reef. This bold reef, which outcrops at about 40 feet from the boundary of the Bow Bells lease, measures about 20 feet in its widest part, and can be followed along the surface for about 484 feet. The eastern end of the reef bifurcates, and both horns of the fork gradually dwindle out to threads of quartz. The western end of the reef is about 50 feet from the north-west angle of G.M.L. 505.

Great Western, G.M.L. 502.—An abandoned 12-acre lease lying in the main belt some distance to the south-east of the Bow Bells. Some desultory work has been done upon a well defined reef, varying from 1 to 5 feet in thickness. The reef occurs in a very much crushed greenstone. The quartz in places contains veins and eyes of banded bright green serpentine [5772] which present every appearance of having been produced by shearing. The reef is in all probability along (or parallel to) the same line of fracture which carries the Main Bow Bells Reef. The quartz is of a white colour, and practically destitute of any other mineral, except a very little pyrites, closely associated with the green serpentine previously referred to. A parallel reef occurs near

the south-eastern angle of the lease, but no work has been done upon it.

In 1898, when the property was visited by the then Inspector of Mines, Mr. Gladstone, about 100 tons of quartz had been raised from the first lease, and awaited treatment. No separate crushings from this lease appear in the returns; any returns are in all probability included under the heading of the yield from sundry claims.

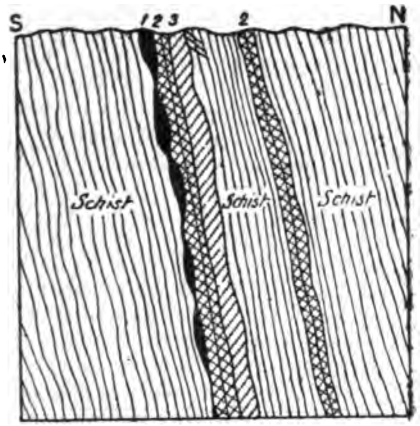
A tunnel had been put in 55 feet on a bearing of 223 degrees, on the vacant ground lying between this lease and that adjoining G.M.L. 595; the tunnel had been carried through decomposed schist underlying to the north-east. At about 35 feet from the mouth of the tunnel there is about from six to eight inches of quartz exposed, which represents the continuation of the reef opened up in G.M.L. 502; the face of the tunnel exposes a thin vein of quartz of from two to three inches in thickness.

GAUNTLET NO. 3 NOR'-WEST, G.M.L. 595 (*late* Gift).—This abandoned 24-acre lease is traversed by two principal reefs which have been worked at one time or another by three shafts. The most northerly shaft, which is inaccessible, has been sunk to a depth of 15 feet on a reef having a general strike of 107 degrees, with a high underlay to the north. A little stone has been taken out from the reef, which, judging from the ore at grass, had a maximum thickness of 12 inches. So far as may be seen in the sides of the shaft the reef is represented by three or four quartz veins about a couple of inches in thickness. The same reef has been opened up at intervals along the outcrop for a distance of about 100 feet eastwards from the shaft; in one place the reef measures from two to three feet across. A very little stone has been raised and is now stacked; the quartz is of a pure white colour and contains small quantities of iron ore; a sample [5774] of it assayed gold at the rate of 1dwt. 15grs. per ton.

The principal workings on the lease, however, are on the vein lying to the south-west of the laminated quartz vein and about 148 feet from it. Two shafts, 94 feet apart, have been put down upon the vein. The south-eastern shaft (No. 2) is inaccessible, and no information is available; the vein has been opened up along the surface for a distance of 38 feet along the outcrop south-east from this shaft, but owing to the condition of the workings little is to be seen of it. No. 1, or the westernmost shaft, is distant 94 feet from No. 2, and the stone has been worked right to the surface between the two but from what depth cannot be ascertained. This shaft, the depth of which is unknown, has water standing in it to about 35 feet from the surface, and is now used as a well. Owing to the influx of water, it is asserted, the property had to be abandoned.

Fig. 9 gives a section across the reef, which lies along a line of fault, the hanging wall of which is marked by a somewhat puckered and greatly slickensided vein of quartz.

Fig. 9.



SECTION ACROSS THE GIFT REEF G.M.L. 595.
WARRAWOONA PILBARA G.F
1 Gift Reef along line of Fault 2 White Quartz 3 Black Quartz,

This vein is the continuation of Kopcke's Leader.

The following table gives the yield of this reef so far as can be ascertained from official data.

Table showing the Yield of the Gift Reef.

Year.	Ore Crushed.	Gold therefrom.	Rate per ton.
	tons.	ozs.	ozs.
1898	11·80	23·50	1·99
1899	32·25	50·00	1·55
Totals	**44·05**	**73·50**	**1·66**

Golden Gauntlet, G.M.L., 506.—This lease adjoins the Gift, on the east; a fair amount of work has been done at the north-west end of the property, on a reef which occurs, as may be seen by an inspection of the geological map, in close proximity to where the main laminated quartz vein is traversed by the greenstone dyke [5773].

A tunnel has been put into the face of the hill on a bearing of 240 degrees, for a distance of about 75 feet. At 34 feet from the mouth of the tunnel, the laminated quartz vein has been met with,

and passed through at 47 feet, giving a thickness of 13 feet; the vein underlays to the north-east at 85 degrees. At the face of the tunnel the decomposed rock is much less foliated than that exposed in the rest of the tunnel, thus indicating a gradual decrease in foliation as one approaches, and receded from the quartz vein. There does not appear to have been much obtained from this tunnel, which would seem to have been driven for the purpose of exploring the laminated quartz vein at some depth below its outcrop. Two shafts, now inaccessible, have been put down on a large reef situated a little distance to the north of the tunnel which has an average strike of 146 degrees. The most northerly shaft, 35 feet deep, is distant 95 feet from the southernmost; from the foot of the northern shaft a drive has been put in along the reef in both directions, but no particulars are obtainable. The thickness of the reef as measured on the outcrop, close to the northern shaft, is 20 feet, and probably merely represents the widest portion of a bulge in the reef. The quartz is of a bluish white colour, and appears to contain no accessory minerals. A fair quantity of outcrop stone has been stacked and awaits crushing.

Table showing the Yield of the Golden Gauntlet Reef.

Year.	Ore crushed.	Gold therefrom.	Rate per ton.
	tons.	ozs.	ozs.
1899	3·00	4·60	1·53

GAUNTLET, G.M.L. 483.—The Gauntlet Lease was originally taken up in the year, 1898, by Mr. R. H. Mackenzie; it comprises an area of 12 acres, and has been responsible for a yield of 3,693ozs. of gold, or 2·86ozs. for every ton of ore milled up to the close of 1903.

The surface of the lease is occupied by greenstone schists and allied rocks, whilst skirting the southern boundary is a continuous and conspicuous band of laminated quartz about 10 feet in thickness. The foliated greenstone contains large crystals of iron ore, identical with those weathering out of the massive variety.

There are practically four principal reefs, *i.e.*, reefs upon which any work has been done, on the ground, the longest having a length along the outcrop of at least 400 feet, and the shortest about 100 feet (Plate V.). When the position of the reefs is accurately laid down upon a plan, it is noticed that they exhibit, with minor variations, a rude parallelism, the general strike being north-west and south-east, which coincides with that of the foliation and dominant structural features of the district. About 45 feet north of the band of laminated quartz is a fairly continuous quartz reef outcropping for about 500 feet from the north-western boundary of the property. This reef attains a thickness of about two feet in

places, though as a rule very thin, it is perhaps the one which exhibits the greatest linear persistence on the lease.

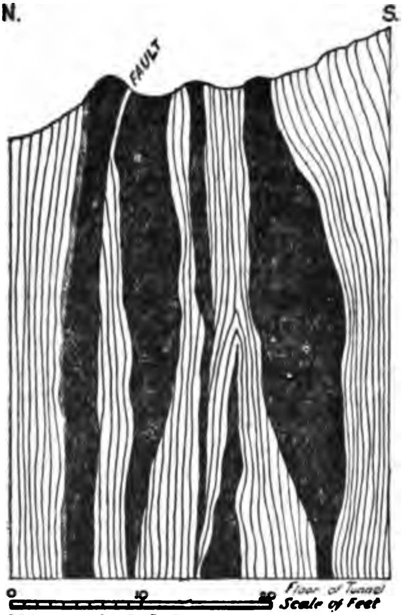
The South Reef.—The South Reef, which has been opened up by means of a tunnel and several small open-works, can be traced across the surface for about 140 feet. The tunnel has been driven about 31 feet in a southerly direction; at its mouth the reef, merely an exceptionally large lenticular mass of quartz, the maximum thickness of which measures 2 feet 3 inches, has been exposed. The country rock in the tunnel is decomposed schist, with small lenticular "eyes" of quartz developed along shear planes. The open-works on this line merely expose a similar succession of quartz lenticules. In view of the fact that their mode of occurrence is identical with those on that important line, Kopcke's Leader (*q.v.*), and that they are said to be appreciably auriferous, this line would seem to merit a certain amount of judicious prospecting.

The Main Reef.—As developed to the south of the main shaft, from which it is distant 40 feet, the main reef has a continuous outcrop of 132 feet; the eastern end of the outcrop originates as a mere thread of quartz, which gradually increases in size until it reaches a maximum thickness of 10 feet. At the western extremity, where it is truncated by a fault, to which reference will be made later, the reef is about six feet in thickness. As shown in the large open cut at the surface, the main reef is intersected by two faults, making an angle of about 55 degrees. What may be called the main or cross fault has a general strike of 163 degrees, and the strike fault, 110 degrees. Fig. 10 shows what may be called the "compound" nature of the reef as exposed in the open cut, the tunnel, and the lowest portion of the workings at the present time. There is a total thickness of about 16 feet of quartz exposed in the open cut, 14 feet in the tunnel, and about 12 feet at the bottom workings. The main reef has been opened up by means of a vertical shaft (the main shaft) 126 feet 6 inches in depth and a tunnel 168 feet in length. The shaft, which is eight feet by four feet, intersected the reef at 101 feet from the surface, and had been carried down through a foliated green rock. East and west drives, 95 and 201 feet respectively, have been put in at 101 feet; at 116 feet in the shaft is water level, of which there is 10 feet standing.

The tunnel has been put in at a point 85 feet west of the main shaft, about 20 feet vertically below it, and intersects the bottom of the open cut previously alluded to. At about 32 feet from the mouth of the tunnel a winze has been carried down along the plane of the fault to the western end of the drive from the main shaft 87 feet vertically below the level of the floor of the tunnel. Fig. 10 is a section of the reefs, etc., seen in the tunnel at the foot of the open-cut. From this point the tunnel has been carried through foliated country rock, with quartz leaders; on nearing the face of the tunnel the schist becomes much more siliceous, suggesting the proximity of the laminated quartz vein which occupies the surface of the southern boundary of the lease.

The whole of the stone has been taken out from the floor of the tunnel to the surface, 38 feet vertically above it, and from this spot practically the whole of the 3,693ozs. of gold, as shown in the return

FIG. 10.



SECTION OF THE GAUNTLET MAIN REEF
WARRAWOONA PILBARA G.F

appended, was obtained. From what can be seen in this portion of the mine, it appears that the ore chute lies in, or in close proximity to, the acute angle formed by the two principal faults alluded to previously; the positions of these are delineated on the plan of the reefs and underground workings (Plate V.).

The main reef has been met with in the west level, opened out from the end of the crosscut, 38 feet in length, south from the main shaft. The reef first makes its appearance as a mere thread of quartz at a point in the drive 23 feet east from the centre of the crosscut; at this spot it measures from six to eight inches in thickness, and gradually increases towards the face. At one point in the drive the reef measures fully eight feet of solid quartz; powerfully slickensided faces on the foot-wall demonstrate that the reef occurs along a line of fault. The slickensides hade in the same direction as the underlay of the reef, to the northwards. The end of this level intersects the winze from the tunnel overhead, and has been carried down 16 feet 6

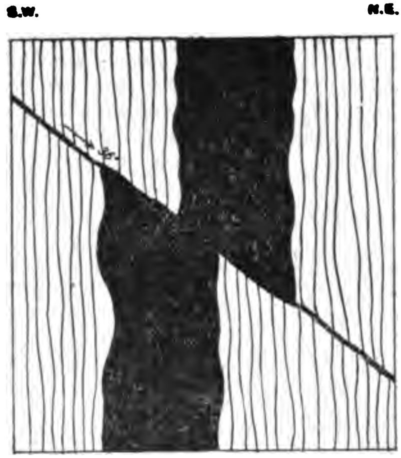
inches from the floor of the drive. At the mouth of the winze the main reef measures three feet nine inches; whilst at its foot it is four feet eight inches, with a thin band of schist. Thirteen feet from the north face is a second reef of 24 inches, separated from a third of three feet by ten inches of schist. This section agrees in the main with that occurring in the tunnel at the foot of the open cut, in that there are three bodies of quartz separated by varying thicknesses of schist. The main fault leaves the south drive at a point 26 feet from the foot of the winze on the eastern wall, and does not appear to have been followed. The drive is continued about 22 feet from this point on the western wall of the fault through schist containing thin ribbons of quartz and small cubical crystals of pyrites. An important feature in this winze is an almost horizontal fault, or thrust plane, hading to the north at about five degrees, with a horizontal displacement of from 12 to 18 inches to the rise. The fault fissure measures less than six inches filled with quartz, which may merely represent a flat leader of secondary origin. The floor of the drive, as ascertained by a trench put in across the mullock with which it had been filled, showed that the reef occurred below the horizontal fault. Free gold is showing freely in the solid stone [5785]. The bottom of the winze is at water level.

The main fault traverses the whole breadth of the lease, and abruptly truncates a bold reef lying some distance north of the north-eastern boundary of the property. There seems to be good reason to regard the reef lying to the west of the fault, and about 120 feet from the mouth of the tunnel, as being the western extension of the main reef. This reef lies near the centre of the lease, and makes a bold outcrop of nearly 300 feet in length; it is, in places, of considerable thickness, and the general mineralogical character of the quartz agrees very closely with that which forms the main reef itself. This possible extension of the main reef, more especially where it is truncated by the fault, has not been prospected. I understand appreciable quantities of gold have been obtained there. There are two other smaller reefs, shown on the plan (Plate V.), in close proximity to this one; these also have not been prospected.

The East Reef.—The East Reef, as showing on the surface, has an outcrop of 275 feet in length, and a width of about eight feet in its widest part; both ends of the outcrop are represented by thin threads of quartz. The reef has been opened up both from the main shaft and the east shaft, which is 95 feet in vertical depth, and has been sunk on the reef the whole way. The reef makes its appearance in the eastern drive from the main shaft at a point about 50 or 60 feet from the eastern shaft, where it is represented by a thread of quartz, which gradually increases in thickness until it occupies the full width of the roof of the drive, and attains a maximum thickness of eight feet. There is at this level a blank space of about 50 feet between the end of the main and the east reef, though at the surface the

extent of dead ground is not so great. At the surface the two extremities of the reef are about 14 feet apart in a direction at right angles to the underlay, and, underground, at 100 feet vertically below, the distance is barely 10 feet. Beyond the stone taken out of this reef in sinking the shaft, driving the level, and a little from the small open cut on the surface, no further work has been done. The foot of the eastern shaft also exposes a reverse fault, Fig. 11, which has a throw of about two feet, and a hade of 35 degrees to north 75 degrees east.* The quartz exposed in the shaft averages about three feet in thickness.

FIG. 11.



SECTION OF A REVERSE FAULT IN THE GAUNTLET MAIN REEF AT No 1 LEVEL. WARRAWOONA PILBARA GF

The North Reef.—The North Reef lies on the opposite side of the valley which traverses the central portion of the Gauntlet lease longitudinally, at a considerable elevation above the lowest portion of the ground. The reef outcrops at an average distance of about 90 feet from the north-eastern boundary of the lease, and occupies the surface for a distance of about 440 feet. The north-western end of the outcrop of the reef bifurcates, with an extension of the reef to the north-east of about 40 feet. At this point the stone, which is about four feet thick, is abruptly truncated by a fault, which also cuts off a larger reef, 160 feet in length, at a point about 200 feet to the south-east. This latter reef makes a very pronounced outcrop, and is of considerable thickness. A vertical shaft, 29 feet deep, has been sunk at a point near the thickest portion of the north reef, but beyond this no other work has been done upon it.

* By an error Fig. 11 gives the section as being in the main reef, whereas it should be the east reef.

The following table gives the yield of this lease, the gold having been entirely derived from the stone occurring at the faulted extremity of the main reef:—

Table showing the Yield of the Gauntlet Reef.

Year.	Ore crushed.	Gold therefrom.	Rate per ton.
	tons.	ozs.	ozs.
1898	106·20	430·90	4·05
1899	150·10	736·15	4·90
1900	872·00	2,269·00	2·60
1901	136·50	238·05	1·74
1902	24·50	19·45	·79
1903	*Nil*	*Nil*	*Nil*
Total	**1,289·30**	**3,693·55**	**2·86**

Rangatira, G.M.L. 491.—An abandoned lease, adjoining the Gauntlet, on the south. The property is traversed by two reefs, upon which a little desultory work has been done. A small crushing, particulars of which are given below, has been obtained from this lease.

Table showing the Yield of the Rangatira Reef.

Year.	Ore crushed.	Gold therefrom.	Rate per ton.
	tons.	ozs.	ozs.
1899	8·50	5·15	·60

Gauntlet East, G.M.L. 560.—The north-western boundary of this lease is traversed by what may be the faulted extension of the East Reef of the Gauntlet. An inaccessible vertical shaft has been sunk upon it, but nothing can be seen of the reef and its behaviour underground. To the eastward and not far to the west of the Treble Event boundary, a tunnel 55 feet in length has been driven on a bearing of 296 degrees, through a fine-grained quartz schist [5789] traversed by a deposit of the leader type. Nothing, however, beyond this has been done on the property.

There do not appear to have been any crushings recorded from this lease, unless such are included in the yield of those from sundry claims.

Imperialist, G.M.L. 564.—The Imperialist reef lies about 400 feet to the south of what may be called the main reef series of Warrawoona. The reef can be followed more or less interruptedly along the surface for a distance of at least 2,200 feet south-east, and as may be seen by an inspection of the Geological Sketch Map (Plate III.), there seems to be good reason to believe that it may extend much further than this.

The Imperialist has been exploited by three principal shafts, all of which are situated near the western extremity of the outcrop. No work was being carried out at the date the property was visited and the main shaft had been dismantled.

The westernmost shaft (now filled in) is situated near the western extremity of the outcrop of the reef, which at this point strikes 101 degrees. Judging by the condition of the dump and the workings a fair amount of work must have been done from this shaft. Between this point and the Central shaft, 114 feet distant, the reef has been opened out at one or two places, and about 12 inches of quartz exposed. A considerable amount of work has obviously been done from the Central shaft; this shaft, which exposes from 6 to 12 inches of quartz, is inaccessible. The main shaft bears 97 degrees from the Central, and is 83 feet distant from it. Water stands in the shaft at 80 feet from the surface. The quartz lying at the mouth of the shaft contains fragments of serpentine [5775]—a sample of this quartz yielded, on assay in the Survey laboratory, gold at the rate of 1dwt. 15grs. per ton—and large veins of calcite [5776], some of which are 12 inches in thickness. The calcite yielded a minute trace of gold per ton. The country rock of the reef is [5777] a talc-chlorite schist. The quartz of the Imperialist, so far as may be judged by the stone in the dump, seems to be a replacement of the country rock.

Near the north-east angle of the lease is another parallel reef of from six to eight inches in thickness, upon which a fair amount of work has been done. The reef has been stoped out to the surface from a depth of 20 or 30 feet; the workings, however, are inaccessible. The country rock is schist of the prevailing type. The quartz is traversed by a small vein of calcite. There are three other more or less parallel reefs in the vicinity of the Imperialist, but no work appears to have been done upon any of them.

The following table gives the yield of the Imperialist reef:—

Table showing the Yield of the Imperialist Reef.

Year.	Ore crushed.	Gold therefrom.	Rate per ton.
	tons.	ozs.	ozs.
1899	163·75	214·01	1·30
1900	367·50	389·20	1·05
1901	17·50	26·30	1·50
1902	*Nil*	*Nil*	...
1903	147·00	181·07	1·23
Totals	**695·75**	**810·58**	**1·16**

Treble Event, G.M.L. 573.—This six-acre lease adjoins the Dodger on the west. Two apparently deep shafts have been put down upon what appears to be the north-western extension of the

Dodger Reef. Nothing, however, can be seen of the reef at the present time. A small trial crushing, of a little over three tons, has been recorded from this reef in 1902, with the results as shown in the table below:—

Table showing the Yield of the Treble Event Reef.

Year.	Ore crushed.	Gold therefrom.	Rate per ton.
	tons.	ozs.	ozs.
1902	3·25	4·00	1·23

Dodger, G.M.L. 587.—Two shafts have been sunk on a reef, which lies a short distance to the north of the laminated quartz vein, and parallel to it, but at the present time nothing can be seen of the nature of the reef and its behaviour underground.

Klondyke Boulder Block, G.M.L. 577.—No work has apparently been done upon this property, which was evidently taken up with the object of intersecting the Klondyke Boulder Group of reefs at depth on the underlie.

Princess of Alaska, G.M.L. 489.—This is an old abandoned lease which included within its boundaries the three leases 573, 587, and 577. Two small crushings have been recorded from this in 1898 and 1899, but there is, however, nothing to indicate at the present time whether the stone was obtained from the Treble Event, G.M.L. 573 (*q.v.*), or the Dodger, G.M.L. 587 (*q.v.*).

Table showing the Yield of the Princess of Alaska Reef.

Year.	Ore crushed.	Gold therefrom.	Rate per ton.
	tons.	ozs.	ozs.
1898	11·00	33·56	3·05
1899	29·00	37·05	1·27
Total	40·00	70·61	1·76

Klondyke Boulder, G.M.L. 604 (late 476).—This 12-acre lease, which has turned out 2,356ozs. of gold, or at the rate of 2·40ozs. per ton of ore milled, was originally granted to Messrs. Hall and Cook in the year 1898, and was numbered 476. The lease was subsequently re-numbered 604 on its being conditionally surrendered in 1901.

A considerable amount of work has been done upon the property since it was first exploited, but at the date the locality was visited, the lease being under exemption and the main working

full of water, access underground could not be obtained; there appear to be no plans of the workings, hence no information as to the nature and behaviour of the reef below surface is available.

As may be seen by an inspection of the Geological Map (Plate III.), it will be noticed that the surface of the lease is occupied by greenstone schist; the north-eastern portion of the ground is traversed by a narrow but persistent band of very much sheared greenstone, which forms a very pronounced feature on the surface. This band lies about an average distance of 100 feet south of the conspicuous laminated quartz vein which traverses the field.

All the reefs lie to the south of the laminated quartz vein; they, however, do not occur in that zone which embraces the Bow Bells and the Gauntlet reefs. The Klondyke Boulder reefs present many features in common with those of the two properties mentioned above. The position of the reefs, etc., is shown on the plan which forms Plate VI.

There are two distinct types of ore deposits on the property, the most persistent being that which may be conveniently termed the leader, which trends generally north-west and south-east, and has an outcrop of not less than 650 feet; the second type being that of the main reef, which has a much more westerly trend than that of the leader.

The Leader has been opened up at six or seven places on the lease, but in only one spot (E) does any very serious attempt appear to have been made to exploit it. At this spot a vertical shaft had been put down on a shear plane underlying at a very high angle to the south-west. The shaft proved to be inaccessible; but from what could be seen on the south-eastern wall the reef consisted of eye-shaped masses of quartz encased in slickensided faces of older quartz, about three to four inches in thickness. There is every geological reason for believing that this reef is merely the north-western extension of Kopcke's leader (*q.v.*).

The Main Reef consists of a vein of quartz, having an outcrop measuring about 130 feet in length; it has been worked by means of two shafts, B and C. Shaft B measures 25 feet in depth, and from it is an open cut 83 feet in length, in which a somewhat tortuous quartz reef is exposed; little, however, is to be seen of it at the present time, though in one place there is about 12 inches of quartz exposed. At the south-west end of the open cut, and about three feet from the main reef and on the north side of it, is a large lenticular mass of bluish-white quartz several feet in thickness. Its position is shown on the plan of the reefs forming Plate VI. There seem good reasons for believing the main reef and this lenticular mass of quartz to be separated by a fault hading to the north. Between this lens and shaft E is another boomerang (kylie) shaped mass of quartz about 80 feet in length. Shaft C, 21 feet northwards from B, is also inaccessible. Water is standing in the shaft;

to the top of the water is 84 feet. About 55 feet north-west from the shaft B is another vertical shaft 44 (?) feet deep, sunk with the intention of working the small reef, shown on the plan, outcropping for about 50 feet, and lying a little distance to the south.

To the north-west is a tortuous reef, which occupies the surface for about 140 feet. The reef, which is well seen in the open cut, along its outcrop is traversed by two faults, as shown on the plan (Plate VI.). The southernmost fault is continuous in a south-easterly direction and probably extends as far as that which truncates the reef outcropping at A, referred to later on.

At A is a quartz reef of three feet ten inches in thickness and 70 feet in length, cut off by an almost north and south fault. This fault, which is exposed in a shallow shaft nine feet deep, underlies in a direction north 65 degrees east at an angle of 24 degrees. A section is given on Plate VI. showing this fault; it is, however, taken across the reef and not in the direction of the true dip. There seem good grounds for believing this to be a reverse fault.

The main shaft workings are inaccessible, hence there are no data as to the nature, thickness, and other cognate points of the reef.

The following table shows the yield of this property :—

Table showing the Yield of the Klondyke Boulder Reef.

Year.	Ore crushed.	Gold therefrom.	Rate per ton.
	tons.	ozs.	ozs.
1898	90·45	879·14	4·19
1899	262·45	526·28	2·00
1900	253·71	436·55	1·72
1901	92·50	287·60	3·10
1902	81·05	159·65	1·97
1903	198·00	567·00	2·86
1904	38·00	94·71	2·49
Total	1,016·16	2,450·93	2·41

Wheel of Fortune, G.M.L. 611 (formerly G.M.L. 571, and Dawson City, G.M.L. 477).—There are two well-defined reefs on the property, both of which lie some distance to the north of the conspicuous laminated quartz vein which occupies the southern boundary of the lease. Several shafts have been put down, to depths not known to me, upon that well-defined quartz reef, which lies about 100 feet north of the laminated quartz vein. In August, 1898, Mr. Inspector Gladstone mentions the depths of three of these shafts as being, respectively, 50, 35, and 50 feet, the latter one

being on a reef three feet in thickness. The reef, as exposed at the surface, is of that bluish-white colour, which characterises the reefs of Bow Bells and Gauntlet types.

Some of the quartz [5791] contains quantities of the red oxide and the green carbonate of copper, together with films of sericitic mica and a little serpentine. A sample of the characteristic cupriferous variety [5791] assayed in the Survey laboratory: gold, 4dwts. 2grs. per ton, and copper 1·23 per cent. There have been four crushings recorded from this property, details of which are given in the table below:—

Table showing the Yield of the Wheel of Fortune Reef.

Year.	Ore crushed.	Gold therefrom.	Rate per ton.
	tons.	ozs.	ozs.
1898	25·60	6·90	·27
1899	*Nil*	*Nil*	...
1900	96·50	99·95	1·03
1901	16·50	11·50	·70
1902	67·75	131·60	1·94
Totals	**206·35**	**249·95**	**1·21**

Nelson, G.M.L. 514.—A shallow shaft has been sunk upon a prominent east and west reef, situated near the north-west angle of the property, but very little work appears to have been done upon it. A small trial crushing was obtained from this reef in the year 1898, with the result as shown in the table.

Table showing the Yield of the Nelson Reef.

Year.	Ore crushed.	Gold therefrom.	Rate per ton.
	tons.	ozs.	ozs.
1898	**1·25**	**5·29**	**4·23**

Klondyke No. 1 West, G.M.L. 578 (formerly Klondyke No. 1, G.M.L. 474).—The leader, lying to the south of the laminated quartz vein, traverses the whole length of the property, and all the work done on the lease appears to have been concentrated on it. Two inaccessible shafts have been put down on the leader, but at the present time there is nothing to be seen of anything underground.

Writing in 1898 Mr. Inspector Gladstone mentioned that the one shaft then sunk had attained a depth of 60 feet, and exposed "a rich leader with three-feet lode formation."

The official returns shown in the table below demonstrate that the leader was rich, crushing nearly at the rate of $4\frac{1}{2}$ozs. per ton.

Table showing the Yield of the Klondyke No. 1 West Reef.

Year.	Ore crushed.	Gold therefrom.	Rate per ton.
	tons.	ozs.	ozs.
1898	5·00	37·77	7·55
1899	14·95	63·20	4·22
1900	23·05	88·70	3·84
Total	**43·00**	**189·67**	**4·41**

Klondyke Block, G.M.L. 507.—This 18-acre lease lies north of, and adjoins the Klondyke property. Six well-defined reefs traverse a portion of the property, but no serious work seems to have been done upon any of them. Two of the reefs are of the bluish colour which characterises the quartz of the Bow Bells and Gauntlet reefs.

A crushing of 37 tons has been recorded in the year 1898, the yield of which being shown in the table below :—

Table showing the Yield of the Klondyke Block Reef.

Year.	Ore crushed.	Gold therefrom.	Rate per ton.
	tons.	ozs.	ozs.
1898	**37·00**	**764·00**	**20·65**

Klondyke, G.M.L. 473 (now called the Klondyke Queen, G.M.L. 627.)—The Klondyke Lease comprises an area of six acres. and was originally taken up by Messrs. Poutt and Corboy in the year 1898; it eventually passed into the hands of the present owners Messrs. Royer and Elliott some time during the year 1903. This lease, as may be seen by the geological map, occupies the same zone as that which embraces the Klondyke Boulder mine, G.M.L. 604, from which it is distant 28 chains to the south-east. The surface of the property is occupied by the quartzitic rocks, and is traversed by the conspicuous vein of laminated quartz which forms the backbone of the district.

Judging by the condition of the surface a fair amount of work must have been done upon the lease; according to the official records 706·75 tons of ore have been raised, which yielded 4,700·76ozs. of gold, or at the rate of 6·65ozs. per ton of stone crushed.

When the property was visited the lease was not being worked, and owing to there apparently being no plans of the workings, very little information as to the nature and behaviour of the deposits is available. The Klondyke reef, as may be seen by the geological map, lies a little distance to the north of the leader.

The Main Reef enters the lease on its eastern boundary, where it has been open cut for about 27 feet; there is about a foot of quartz now showing. To a point about 117 feet east of this the reef has hardly been touched, it measures, however, four feet across; at this point is the mouth of a tunnel, put in along the reef for a distance of at least 300 feet. Seventy-two feet from the mouth of the tunnel is a winze, inaccessible at the present time, and said to be 90 feet; at this point there is 12 to 14 inches of quartz exposed over-head in the tunnel. The chute of gold followed from the mouth of the tunnel and by the winze is said to be 40 feet wide, with an underlay to the west. The reef has been practically stoped out to the surface to a point from the floor of the tunnel, about 129 feet from its mouth.

A vertical or main shaft connects with a point a few feet to the south of the drive, at a distance of 258 feet from the entrance to the tunnel. Judging from the condition of the workings, the tunnel did not follow the main reef, but merely a thin spur going off to the west.

Free gold is showing in the stone on the outcrop at a point about 50 feet west from the main shaft.

The following table shows the yield of the Klondyke Reef :—

Table showing the Yield of the Klondyke Reef.

Year.	Ore crushed.	Gold therefrom.	Rate per ton.
	tons.	ozs.	ozs.
1898	63·00	836·00	13·27
1899	347·00	1,758·86	5·06
1900	144·50	1,566·20	10·83
1901	86·75	294·40	3·39
1902	65·50	245·30	3·74
1903	*Nil*	*Nil*	...
1904	25·00	83·64*	3·34
Total	731·75	4,784·40	6·53

* Includes 7·33ozs. obtained by cyaniding 9 tons of sands, the balance being returned from what is now known as the Klondyke Queen, G.M.L. 627.

Klondyke No. 1 East, G.M.L. 480.—This six-acre lease adjoins the Klondyke on the east, and is traversed by the leader, which crosses the whole length of the property.

A tunnel has been put in eastwards from the level of the creek, for an unknown distance, on a reef which bears 287 degrees

30 minutes. Further east along the outcrop is a vertical shaft 32 feet in depth, designed to connect with the tunnel below. The reef, as exposed on the surface, is about two feet in thickness. From its relative position there are good grounds for believing this reef to be the eastern extension of the Klondyke. There do not seem to have been any crushings from this property, unless such are included in returns from Sundry Claims.

Brought to Light, G.M.L. 516.—This three-acre lease lies within that zone which includes the Bow Bells and Gauntlet Reefs. There are four well-defined reefs outcropping on the property, but upon one only has any work been done, viz., that near the north-west angle of the adjoining lease number 515. This reef has been opened out along the outcrop for a distance of 50 feet, and in the open cut a vertical shaft 21 feet in depth has been sunk on the reef, which is about 12 inches in thickness. So far as can be seen the reef appears to have petered out at the foot of the shaft.

A small crushing of a little over eight tons has been recorded from this reef, and its yield is shown in the table below.

Table showing the Yield of the Brought to Light Reef.

Year.	Ore crushed.	Gold therefrom.	Rate per ton.
	tons.	ozs.	ozs.
1899	8·75	7·96	·90

The Early Morn, G.M.L. 515.—There are two or three well-defined reefs outcropping on this property, but upon none of them has any work been done.

Klondyke No. 2 East, G.M.L. 481.—This lease adjoins the G.M.L. 478 on the north-west, and, like it, is traversed along its whole length by the leader. This, which occupies the southern portion of the property, has been opened out in one or two places.

A tunnel, the mouth of which is 35 feet north of the leader, and at a slightly higher level, has been put in, through vertical decomposed schists, for a distance of 84 feet, on a bearing of north 35 degrees east. With the exception of a few irregular quartz leaders, nothing of any importance seems to have been met with. A vertical shaft, designed to intersect this tunnel, was commenced, but after being carried down 10 feet work was abandoned. A second tunnel, 20 feet in length, has been put in at some distance from the longer one, but so far nothing is to be seen. There are two other reefs lying to the north of the leader, but nothing has been done upon them.

There seems to have been no crushings recorded from this lease, unless any such are included in the returns from Sundry Claims.

Admiral Dewey, G.M.L. 500.—This twelve-acre lease is situated due south of and adjoins G.M.L.s 478 and 481. There are several reefs traversing the property, the most conspicuous and persistent being that which outcrops along the southern boundary of the lease. The outcrop of the reef is interrupted in two places, as may be seen by an inspection of the plan. The country rock of these reefs is greenstone schist of the prevailing type. The only work carried out on this property is near the centre of the northern boundary, where a trench 16 feet long has been put in across the summit of a narrow ridge to a depth of four or five feet, in which an irregular network of quartz veins and leaders is exposed. The strike of the leaders is parallel to the enclosing schists.

There appears to have been only one crushing recorded from this lease, as shown in the return.

Table showing the Yield of the Admiral Dewey Reef.

Year.	Ore crushed.	Gold therefrom.	Rate per ton.
	tons.	ozs.	ozs.
1898	8·45	4·55	·53

Klondyke King Blocks No. 1, G.M.L. 511.—This lease lies due north of and adjoins G.M.L. 578; it is traversed by two well-defined reefs, which lie within that zone, embracing the Gauntlet and the Bow Bells reefs.

No work of any kind, however, has been done upon these reefs.

Klondyke King, G.M.L. 478.—This six-acre lease adjoins the Klondyke Queen on the west, and, like it, is traversed by the leader, as well as two other reefs of minor importance on the north. The property, however, has long since been abandoned, though a fair quantity of work has apparently been done upon it.

A tunnel 44 feet in length has been put in on a bearing of 27 degrees through the schists to the leader, which has been connected with the surface by a shaft 31 feet deep. The workings from the tunnel are connected with another shaft 24 feet deep, and situated 48 feet to the west.

The leader, so far as it can be seen, does not present any essential points of difference to that in other portions of the field.

Klondyke Queen, G.M.L. 488.—The leader traverses the whole length of the lease on the southern flanks of the laminated quartz vein, but the former does not appear to have been opened out at all. The only work done upon the property is the sinking of a vertical shaft 32 feet deep on a very short east and west reef situated at a point 54 feet north of the laminated quartz vein. An open cut extends south from the vertical shaft and exposes decomposed country rock of the prevailing type.

The only crushing recorded from this lease must have been taken from the east and west reef, previously alluded to. The returns are shown in the table below:—

Table showing the Yield of the Klondyke Queen Reef.

Year.	Ore crushed.	Gold therefrom.	Rate per ton.
	tons.	ozs.	ozs.
1898	**9·90**	**13·75**	**1·38**

KLONDYKE QUEEN EXTENDED, G.M.L. 503.—A small three-acre lease, adjoining the Dead Camel, on the north-west. The property is traversed by the north-western extension of the leader, a fair amount of work having been done along its outcrop, but only to a very shallow depth. There appear to have been no crushings recorded from this property, unless such are included in the returns from Sundry Claims.

To the south of G.M.L. 503 is a faulted inlier of quartzite, in the form of a large attenuated lens, of considerable length but no great breadth. This, however, is too small to be shown on the geological map accompanying the report.

DEAD CAMEL, G.M.L. 475.—The "leader" is continuous through this property, and has been worked for about 100 feet along the outcrop.

A vertical shaft 91 feet in depth has been sunk at one point on the outcrop. Below a depth of 84 feet nothing can be seen of the leader, owing to the shaft being filled in. At the foot of the shaft, so far as can be at present seen, the reef is of the usual lens-shaped type: the lenses being up to eight inches in thickness, and up to 18 inches in depth.

Free gold is showing in the stone, in addition to pyrites and galena [5786] and serpentine.

In addition to the leader there are two other quartz reefs on the property situated on the north side of the laminated quartz vein, but no work has been done upon them.

The returns from this reef are shown in the table below.

Table showing the Yield of the Dead Camel Reef.

Year.	Ore crushed.	Gold therefrom.	Rate per ton.
	tons.	ozs.	ozs.
1898	2·50	9·10	3·64
1899	16·25	54·40	3·34
Total	**18·75**	**63·50**	**3·38**

Saint George No. 1 West, G.M.L. 498.—The reef outcropping in the Saint George traverses the eastern portion of this lease, but little is to be seen. Mr. Inspector Gladstone reports that "an open cut has been worked on the reef. Two shafts have been started and are down* about 10 feet. The reef here is two feet six inches thick."

Saint George, G.M.L. 493.—The 12-acre lease, the Saint George, lies some distance to the north of the leader, and has evidently been abandoned for some considerable time. There has evidently been a good deal of work done on the reef at one time or another. Little or nothing, however, can be seen at the present time. Mr. Inspector Gladstone's report, previously alluded to, makes reference to this property in the following terms:—"This is one of the best of the eastern leases on the line. One shaft is down 45 feet, with an open cut about 20 feet. The reef varies from 10 to 15 inches and is very rich in gold. The first crushing gave 110ozs. of gold from 11 tons of quartz." The quartz as showing in the face of the open cut near the shaft is pure white and about one foot in thickness.

The following table gives the yield of this reef:—

Table showing the Yield of the Saint George Reef.

Year.	Ore crushed.	Gold therefrom.	Rate per ton.
	tons.	ozs.	ozs.
1898	20·00	124·00	6·20

Saint George No. 1 East, G.M.L. 499.—Very little work has been done on the reefs traversing this property. There are about three shallow pot-holes, from which about 3 tons of reputedly rich stone have been unearthed.

Last Chance, G.M.L. 540.—An abandoned lease. A fairly well-marked reef, from 12 to 18 inches in thickness, traverses the lease in a north-westerly and south-easterly direction, but beyond opening out the outcrop very little work appears to have been done upon it. The quartz is bluish-white, and contains a little pyrites.

Band of Hope, G.M.L. 533.—An abandoned six-acre lease adjoining G.M.L. 540 on the east. The main reef traversing the adjoining property crosses the northern portion of the Band of Hope; there are also two other veins to the south of it on the ground, trending approximately in the same direction, but no serious work of any kind has been done upon them.

* August, 1898.

Cuban, G.M.L. 492.—A similar condition of affairs prevails on this property as on the Britannia.

The leader, which traverses the whole length of the lease, has been worked to a shallow depth along practically the whole length of the outcrop. At the present time no work is going on, and there is little or nothing to be seen. Mr. Inspector Gladstone's report of 1898 mentions a vertical shaft 20 feet deep, and alludes to a trench 120 feet in length along the outcrop of the leader.

The following table shows the yield of the leader traversing the lease, as obtained from official sources.

Table showing the Yield of the Cuban Reef.

Year.	Ore crushed.	Gold therefrom.	Rate per ton.
	tons.	ozs.	ozs.
1898	5·00	17·08	3·41
1899	18·20	74·33	4·08
1900	28·10	124·00	4·41
Totals	**51·30**	**215·41**	**4·19**

Britannia, G.M.L. 484.—An abandoned six-acre lease, adjoining the Reward and G.M.L. 522 on the west.

A good deal of work has been done along Kopcke's leader, but little can be seen at the present time. Mr. Inspector Gladstone, writing in 1898, metions a vertical shaft 27 feet in depth, and a trench 160 feet in length: none of these are accessible at the present time, hence no description can be given.

The following table gives the returns from this lease:—

Table showing the Yield of the Britannia Reef.

Year.	Ore crushed.	Gold therefrom.	Rate per ton.
	tons.	ozs.	ozs.
1898	9·50	19·85	2·09
1899	9·50	8·85	·93
Total	**19·00**	**28·70**	**1·51**

Kopcke's Reward Block, G.M.L. 522.—There are four short though well-defined reefs outcropping on this lease, but no work of any kind has been done upon them.

REWARD CLAIM 94.—A good deal of work seems to have been done upon this lease. The leader has been worked for a length of 320 feet along the outcrop. There are two vertical shafts 80 feet apart. The western shaft attains a vertical depth of 50 feet, and has been put down on the western end of a slope, along the footwall of the vein. At the foot of the shaft is a quartz lenticule about three inches in thickness; on the hanging wall side of the vein is about eight to twelve inches of laminated quartz, passing gradually into the softer decomposed (aluminous) country rock. The eastern shaft has been carried down to a vertical depth of 130 feet, but has been filled up to a depth of 100 feet. The largest of the quartz lenses exposed attains a maximum thickness of 12 inches, and a minimum of a quarter of an inch. The quartz contains a little pyrites, green carbonate of copper, and a little galena, which latter occurs pretty well all along the leader. Free gold is showing in the stone at grass, of which there was about 40 tons awaiting crushing. The charges for crushing (30s.) and cartage (10s.) amount to about £2 per ton.

The following table gives the yield of this lease:—

Table showing the Yield of Kopcke's Reward Reef.

Year.	Ore crushed.	Gold therefrom.	Rate per ton.
	tons.	ozs.	ozs.
1898	31·00	160·59	5·18
1899	67·85	210·06	3·09
1900	36·25	101·75	2·80
1901	46·25	126·60	2·73
1902	49·70	147·26	2·96
1903	71·50	166·25	2·32
1904	49·00	125·38	2·55
Total	**351·55**	**1,037·89**	**2·95**

WHENNA-PAI, G.M.L. 532.—A small three-acre lease traversed by the leader, upon which a little work has been done, but the workings are inaccessible.

DAYLIGHT, G.M.L., 496.—An abandoned six-acre lease adjoining the Juneau on the west.

A good deal of work has been done at different points along the outcrop of the leader, which traverses the whole length of the property. A tunnel 45 feet in length has been put in eastward, close to the eastern boundary of the lease, and exposes quartz lenticules of the usual type. Mr. Inspector Gladstone, writing in

1898, noted the sinking of a vertical shaft 25 feet deep, but such was not accessible to me.

JUNEAU, G.M.L. 479.—An abandoned six-acre lease adjoining the Criterion on the west. The only work done is an open cut about 120 feet in length put down to a maximum depth of 15 feet upon the line of lenticular quartz veins, the leader. As exposed in the open cut the width of one of these quartz lenses in two inches, and its depth 12 inches. About 100 feet south of the leader is a large ice-like quartz reef parallel to it, and outcropping for about 100 feet along the surface.

Two small crushings have been recorded from this lease, particulars of which are given in the table below.

Table showing the Yield of the Juneau Reef

Year.	Ore crushed.	Gold therefrom.	Rate per ton.
	tons.	ozs.	ozs.
1898	5·75	5·55	·96
1899	8·10	9·78	1·20
Total	**13·85**	**15·33**	**1·10**

CRITERION, G.M.L. 508.—This property, now abandoned, lies at the south-eastern extremity of the long line of leases which extend across Warrawoona. A tunnel has been driven for a distance of 74 feet on a bearing of 208 degrees through decomposed schist inclined at a high angle to the north. At the face of the tunnel the main band of laminated quartz has been pierced. About a foot north from this is a quartz vein made up of small lenticules. Near the mouth of the tunnel is a vertical shaft measuring 29 feet in depth, but inaccessible at the present time. In addition to this and the tunnel, there are other workings, but as these are likewise inaccessible, no description can be given.

Near the south-eastern boundary of G.M.L. 508 (? on Lease 527, the Lucknow) is an open cut 60 feet in length, varying from 5 to 10 feet in depth, from which a vertical lenticular shaped quartz reef (or succession of quartz lenticules) has been extracted. This vein is the eastern extension of Kopcke's Leader. This open cut exposes a quartz reef underlying at 30 degrees in a direction of south 30 degrees east; there is a length of about 15 feet 4 inches exposed. At the surface the reef is 12 inches in thickness, and at

the bottom of the open cut, where it abuts against the leader, it has dwindled to four inches.

Table showing the Yield of the Criterion Reef.

Year.	Ore crushed.	Gold therefrom.	Rate per ton.
	tons.	ozs.	ozs.
1898	8·00	3·30	·41
1899	4·20	4·50	1·07
Total	12·20	7·80	·63

Lone Hand, G.M.L. 512.—The most easterly of all the leases embraced within the limits of the geological map. This property has been abandoned for some considerable time. Operations appear to have been confined to opening up a large and well-defined reef, which traverses the northern boundary of the property. The reef has been opened up in three places, along the outcrop, and where exposed, it varies in thickness from one to two feet. The quartz [5783] is white, and contains the following minerals, the numbers in parentheses indicating their relative frequency:—muscovite (3), limonite (3), malachite (2), pyrites (2), chalcopyrite (1), chalcedony (1), gold (1). In addition carbonate of iron is present in some parts. The reef which underlies to the south has a fairly long outcrop.

Sundry Claims from the District generally.—In addition to the yield of the reefs described above, there are several others which it is impossible to specify, and the returns from which are given in the table below:—

Table showing the Yield from Sundry Claims, Warrawoona.

Year.	Ore crushed.	Gold therefrom.	Rate per ton.
	tons	ozs.	ozs.
1897	5·00	28·93	5·78
1899	187·60	200·82	1·07
		*50·00	...
1900	12·20	32·50	2·66
1901	5·00	5·00	1·00
1902	22·50	35·02	1·55
1903	84·85	332·57	3·91
		†433·30	...
1904	70·45	‡138·45	1·96
Total	387·60	§773·29	1·99

* Alluvial. † Specimens. ‡ Fine gold. § Alluvial and specimens not included in total gold.

Synoptical Table showing the Yield of the Warrawoona Reefs up to the end of 1904.

Name of Reef.	Ore crushed.	Gold therefrom.	Rate per ton.
	tons.	ozs.	ozs.
Admiral Dewey	8·45	4·55	·53
Bow Bells	483·70	855·69	1·76
Bow Bells Block No. 1 ...	12·00	10·50	·87
Britannia	19·00	28·70	1·51
Brought to Light ...	8·75	7·96	·90
Carnoustie	45·40	178·11	3·92
Chance	4·00	8·35	2·08
Criterion	12·20	7·80	·63
Cuban	51·30	215·41	4·19
Cutty Sark	36·05	59·10	1·64
Dead Camel	18·75	63·50	3·38
Gauntlet	1,289·30	3,693·55	2·86
Gift	44·05	73·50	1·66
Golden Gate	59·45	124·50	2·09
Golden Gauntlet	3·00	4·60	1·53
Imperialist	695·75	810·58	1·16
Juneau	13·85	15·33	1·10
Klondyke	731·75	4,784·40	6·53
Klondyke Block	37·00	764·00	20·65
Klondyke Boulder ...	1,016·16	2,450·93	2·41
Klondyke No. 1 West ...	43·00	189·67	4·41
Klondyke Queen	9·90	13·75	1·38
Nelson	1·25	5·29	4·23
Princept	2·15	5·00	2·32
Princess of Alaska ...	40·00	70·61	1·76
Rangatira	8·50	5·15	·60
Reward Claim 94	351·55	1,037·89	2·95
St. George	20·00	124·00	6·20
Tom Thumb	36·55	164·66	4·50
Treble Event	3·25	4·00	1·23
Wheel of Fortune ...	206·35	249·95	1·21
Sundry Claims	387·60	773·29 *50·00 †433·30	1·99
Cyaniding	...	‡6·56	...
Total	5,700·01	17,294·18	3·03

* Alluvial. † Specimens. ‡ Nine tons of sands.

C.—MARBLE BAR.

(With a Geological Sketch Map and Section.)

Marble Bar is the official centre of the Pilbara Goldfield, and the headquarters of the Warden, the Acting Inspector of Mines, and other officials. The relative position of the centre may be seen by a reference to the locality map which forms the frontispiece to this report. The locality derives its name from the picturesque "bar" of jasper which crosses the Coongan River, about two and a half miles to the south-west of the township. The district has had

a somewhat chequered career, and the feverish activity which at one time prevailed has given place to more prosaic conditions.

The mining centre of Marble Bar forms the westernmost extension of that auriferous zone referred to as the Marble Bar, Warrawoona, Yandicoogina, and Mount Elsie Group.*

A geological sketch map, to which is attached a generalised section across the field, designed to illustrate its salient structural features, accompanies this report (Plate VII.). As was the case in most of the other mining fields of the State, by far the larger portion of the area was practically a blank upon any of the existing maps, operations had to be commenced by preparing a plan of the more immediate vicinity of the mines.

Marble Bar lies close to what may be called the Main Range, which presents a fairly bold front to the eastward, and the country is drained by the Coongan River and its tributaries—Duffers and Sandy Creeks.

The Marble Bar centre presents features which link it geologically with Warrawoona and Yandicoogina.

Since the first discovery of the field, about 16 years ago, Marble Bar † has yielded 16,306·74ozs. of gold, resulting from the milling of 8,407·20 tons of ore; these figures give an average of 1·93ozs. of gold per ton. In addition to these figures there have been officially recorded 2,082ozs. from unknown tons, and 82ozs. of specimens, thus bringing the total yield up to 18,470·74ozs.

The various formations represented consist of a series of schists and allied rocks, granites, greenstones, and certain volcanic rocks, which may possibly represent the Nullagine Series as referred to in the earlier pages of the report.

The auriferous reefs of the more immediate vicinity of Marble Bar are embraced within a comparatively narrow belt of greenstone schist, running north and south, and which, as may be seen by an inspection of the Geological Sketch Map (Plate VII.), has a length of a little over three miles.

The district has been subjected to a considerable amount of faulting, and wherever possible the position and extent of these faults have been laid down upon the map.

General Geology.

The different rock masses have as far as possible been mapped, but it has not been found possible to do this in the same detailed way with regard to all the other rocks lying between Marble Bar and the Coongan River.

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* Bulletin No. 15, p. 33 *et seq.*

† *i.e.*, the Marble Bar District as defined by the Mines Department.

I.

PHOTO.: S. J. BECHER

The Marble Bar, Coongan River.

J.

PHOTO.: S. J. BECHER.

Laminated Jaspideous Quartzite, Coongan River, near Marble Bar.

PHOTO.: S. J. BECHER.

Banded Jasper, near The Marble Bar, Coongan River.

Alluvial Deposits.

Most of the watercourses in the district are occupied with a more or less width of alluvium, but in no case did these deposits attain any great thickness, nor are they of any economical importance.

Schists.

By far the largest portion of the district embraced by the geological map is made up of schists, both acidic and basic, which bear a very strong resemblance to those occurring at Warrawoona.

Some of the schists in the vicinity of Hospital Hill, and adjoining the road to Nullagine near the crossing of Sandy Creek, are associated with beds which have every appearance of being transmuted quartzites and conglomerate. Much more detailed investigation, however, than was possible at the time I visited the district is necessary before it can be definitely asserted that these acidic schists are of sedimentary origin. So far, however, as can at present be seen, it appears that these schists are arranged in synclinal trough, as shown in the generalised section at the foot of the Geological Map.

These schists are of economic importance by reason of the fact that they almost invariably form the matrices of the auriferous quartz reefs.

The schists are traversed by two bands of laminated quartz or jasper, the position of which is indicated on the geological map. The most conspicuous, however, is that known as the Marble Bar, which crosses the Coongan River about two and a-half miles south-west of the township. A view of this forms Photograph "I."

The "Bar" is a long razor-backed ridge (Photograph "J.") of laminated quartz or jasper, which rises to a considerable height above the general level of the surrounding country. The width of this band is naturally variable, but in one place near the Coongan River it measures as much as 220 feet from wall to wall. As seen in section, the banded jasper is inclined at an angle of 50 degrees to the north-west. The rocks forming this band can be followed across country for a considerable distance, and form a belt parallel to those similar beds described in Bulletin No. 15. The jaspers [**609, 3593, 3695**] present a brilliant appearance, due to the inter-lamination of red, white, and dark-coloured bands (Photograph "K.") with intermediate varieties, the differences in colour being due to the occurrence of iron in the form of either limonite, hematite, or magnetite. Some portions of the rock contain small but perfect crystals of magnetite.

When carefully examined the banded jasper is found to be much fractured and faulted, Fig. 12 [**609**], some of the cracks thus formed being filled with secondary silica. The occurrence of these cracks filled with secondary silica is such as to cause the stone to break up into slabs and blocks of an extremely irregular size.

The jasper takes an excellent polish and those portions of the rock which may be found free from flaws, etc., could doubtless be

FIG. 12.

Faulted Jasper, Marble Bar.

used for ornamental purposes were its geographical position somewhat more accessible. A typical sample [3695] of this banded jasper which was cut and polished in Europe for use at the Paris and Glasgow Exhibitions is now in the Museum of the Geological Survey.

Granite.

A very large area of country to the east of the township of Marble Bar is occupied by granite. The mass presents in places a very rugged surface, which rises in two conspicuous hills of considerable elevation about due east of the town. The granite presents the same general features throughout its whole extent. In its lithological characters it consists of quartz, felspar, and a little mica. The mass forms one extremity of that granite which embraces the Moolyella Tinfield described in Bulletin No. 15.

Porphyry.

The granite has been invaded by dykes of porphyry [5392, 5612], whilst a very extensive area occurs in the vicinity of Duffer's Creek. In their lithological character these porphyry dykes resemble those of Warrawoona very closely. An analysis of a typical porphyry [5392] is given on page 12 of Bulletin No. 15. These dykes agree very closely with those porphyries of Warrawoona, described in the earlier pages of this report.

Gabbro.

Adjoining that tributary of Duffer's Creek, close to the eastern boundary of the geological map, is a fairly extensive area of a dark green basic rock [5809] which consists of felspar (saussurite?), a ferro-magnesian constituent, which appears to be hypersthene and its alteration products, a little quartz, and an iron ore. Another similar area occurs a little to the south of the Ironclad Mine, G.M.L. 2.

Diabase Dykes.

A very important feature in the geology of Marble Bar is the number of basic dykes, which an examination of the geological map shows have a general easterly trend. The dykes are all readily distinguished by their dark greenish colour, a rusty and in places exfoliating weathering, and in the majority of cases a tending to verticality. The dykes have proved in the vicinity of Marble Bar of considerable value in working out the geological structure of the district. An inspection of the map demonstrates that only in one case do they intersect those sheared greenstones which form the auriferous series.

Owing to the marked features which many of these dykes exhibit on the surface, the mapping of them proved a relatively easy task. These basic rocks form part of that system of dykes which make such a marked feature in certain portions of the Pilbara Goldfield, and to which allusion has been made in the earlier pages of this report, and in Bulletin 15.

An examination of the geological map will show that many of these dykes have been faulted, but in no case does the horizontal shifting appear to have been very great. There are no data, however, by which any estimate of the amount of vertical displacement can be arrived at. The hade of the majority of the faults, however, is to the west, as may be seen in one or two sections. The dykes are all of a fine grain.

Economic Geology.

The Mines.

Although practically none of the mines at Marble Bar were open to my inspection, the following information extracted from the field notebooks of the late Mr. S. J. Becher give some idea of the condition of affairs prevailing, and other cognate points at the time this officer visited these properties.

In order to facilitate description the mines are described in geographical order, commencing at the northern end of the leases. The position of the various properties is shown upon the geological sketch map attached (Plate VII.).

Western Shaw No. 1 North, G.M.L. 291.—The most northerly of all the leases embraced within the area of the map, and traversed by four small quartz reefs, which underlie west. No work, however, appears to have been done upon them. The reefs

are enclosed in the belt of sheared greenstone, which forms the main auriferous series of the district.

IRONCLAD NORTH, G.M.L. 299.—The lease is traversed by a well-defined quartz reef, which extends along the whole length of the eastern boundary of the property, and underlies to the west.

The developments on the property consisted of two vertical and one underlay shaft. One shaft had been carried down to a vertical depth of 25 feet, and continued for a short distance on the reef. A drive had been put in to the north from the foot of the vertical shaft to a point 35 feet distant, where the reef pinched out. Another drive had been continued to the south for 74 feet, and the reef is said to have averaged three feet in thickness, but only crushed, however, 8dwts. to the ton.

The second vertical shaft was 55 feet in depth, but no particulars appear to be obtainable regarding it. The underlay shaft had been carried down 35 feet.

The yield of this reef may have been included under the heading of "Sundry Claims."

IRONCLAD, G.M.L. 2.—The ore deposits on the Ironclad Lease consist of five well-defined reefs, which lie within the belt of greenstone, as shown on the map. The surface of the western half of the lease is occupied by granite, beneath which the sheared greenstone passes. At one time a fifteen-head battery was erected on the property. Near the north-west angle of the lease is the well, near the old battery site, which had been carried down to a vertical depth of 92 feet. In this well the granite extends to a depth of 40 feet, at which point it gives place to schist. The water level is said to have been at 75 feet, and the amount of water which the well made was estimated at 600 gallons per hour.

The northernmost shaft on the field is an underlay put down on the reef at a point about five chains from the northern boundary, but this is at the present time totally inaccessible.

The principal work on the lease has been carried out upon what may be called the main Ironclad reef, which outcrops boldly along a low ridge near the eastern boundary of the lease.

The stone which forms the main reef consists of white quartz, with very ferruginous patches.

A tunnel has been driven in from the side of the hill, along the strike of the reef on a bearing of 141 degrees for a distance of 145 feet, thence 14 feet on a bearing of 182 degrees to a point at which the main reef is first intersected. From this point a drive has been carried along the reef for a distance of at least 138 feet. The reef, as exposed at the first bend in the tunnel, measures three feet in thickness. These workings connect with the surface by two vertical shafts, one being 24 feet deep, and the reef stoped right up to the surface. In this portion of the workings the average thickness of the reef is four feet. The second vertical shaft, 128 feet west, had been carried down to a depth of 87 feet, and intersected the main

reef at 74 feet. A drive is said to have been put in 16 feet south on the reef, which has an average thickness of about 20 inches.

Fig. 13 shows a section across the Ironclad Reef, etc.

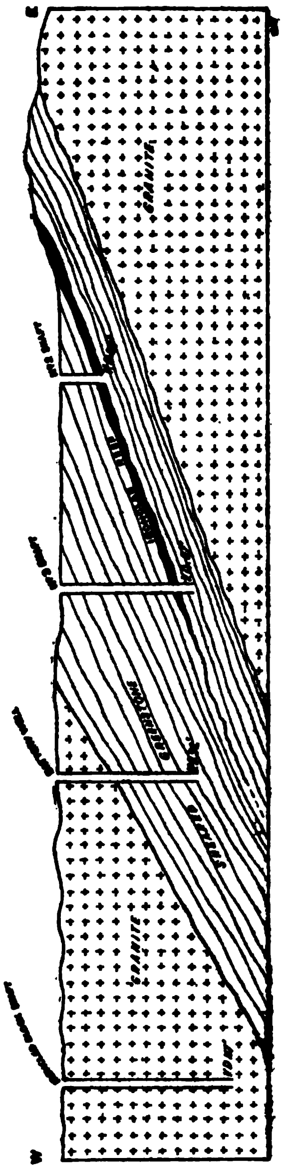


Fig. 13.

SECTION ACROSS THE IRONCLAD REEF MARBLE BAR.

Near the south-east angle of the lease are three inaccessible shafts, not indicated on the map; the northernmost of the group being an underlay put down on the reef to a depth of 120 feet. The reef is said to have attained an average thickness of five feet. A second underlay, some little distance to the south on the same reef, is said to have been carried down to a depth of 40 feet. West of this is a vertical shaft 34 feet deep.

The following table gives, so far as can be ascertained from official sources, the yield of the Ironclad Reef:—

Table showing the Yield of the Ironclad Reef.

Year.	Ore crushed.	Gold therefrom.	Rate per ton.
	tons.	ozs.	ozs.
1893	297·00	774·30*	2·60
1894	94·00	163·00	1·73
1895	1,097·00	258·00	·23
1896	531·00	239·02	·45
1898	21·50	7·25	·34
Total	**2,040·50**	**1,441·57**	**·70**

* Of this amount, 418ozs. has been obtained from a crushing of unknown tons.

Ironclad South, G.M.L. 108.—This is a 24-acre lease, adjoining the Ironclad. There are three small but distinct reefs upon the property, but very little work of any description appears to have been done upon them. An opencut has been put in along the reef, averaging about 12 inches in thickness, which may represent the southern extension of the Ironclad. Three underlay shafts, 34, 54, and 20 feet respectively, have been put down, but these are inaccessible. The principal workings are an underlay shaft, 65 feet in depth, from which drives have been put in east and west for distances stated to be 60 and 20 feet respectively. The only separate record of any crushing from this mine is one in 1895 of 61 tons, which yielded 24ozs. of gold, or at the rate of ·39ozs. per ton.

Ironclad Block, G.M.L. 113.—The surface of the Ironclad Block Lease is occupied by granite, and a vertical shaft has been put down at a point seven chains from the south-east angle of the lease, and designed to intersect the main Ironclad Reef at about 200 feet. This shaft had been carried down to a vertical depth of 117 feet through granite. The relative position of this shaft is shown in Fig. 13, *supra*.

Iron Duke, G.M.L. 387.—This lease embraces part of an area which included the old leases, G.M.Ls. 63 and 8.

A shaft, not shown on the plan, has been put down to a depth of 40 feet, upon an approximately north and south reef, which is

stated to have been of very variable thickness, but to have reached as much as three feet. The reef which underlays west is of white quartz.

In 1896, 40 tons of quartz raised are stated to have yielded 25·70ozs., or at the rate of ·64ozs. per ton.

KEEP-IT-DARK, G.M.L. 296.—This old lease embraces a portion of the abandoned M.L. 8, The General.

A considerable amount of desolutory surface work has been done.

Two vertical shafts, 20 feet in depth, had been sunk upon the eastern extremity of the east and west reef, adjoining the main fault which traverses the property, but these were long ago abandoned. Two other underlay shafts, one of them 12 feet deep, had also been put down, but these were also inaccessible. A crushing of 32·5 tons in 1896 yielded 73·65ozs. of gold, or at the rate of 2·26 ozs. per ton.

The general reef outcrops upon what was originally M.L. 8 (G.M.L. 485) now embraced by G.M.L. 296.

The general reef which outcrops just outside the northern boundary of G.M.L. 296 is a well-defined body of quartz, striking north and south and underlying at an angle of between 40 and 50 degrees to the east. This reef has been extensively worked by the previous holders of the lease. The reef has been followed down from the surface for a distance of over 180 feet. A vertical shaft (Fig. 14) about 50 feet in depth intersected the reef, which was followed down for a further distance of 150 feet. The reef was abruptly cut off by a fault underlying west, but the shaft was continued for a further distance of 30 feet through country rock. A good deal of work appears to have been done underground, but there was very little to be seen at the present time. The fault seen at the bottom of the shaft is also visible in the workings at the eastern end of No. 1 level; the fault also underlies to the west. There are several faults in the vicinity of the reef, some of which are shown on the geological map (Plate VII.) so far as the small scale will admit.

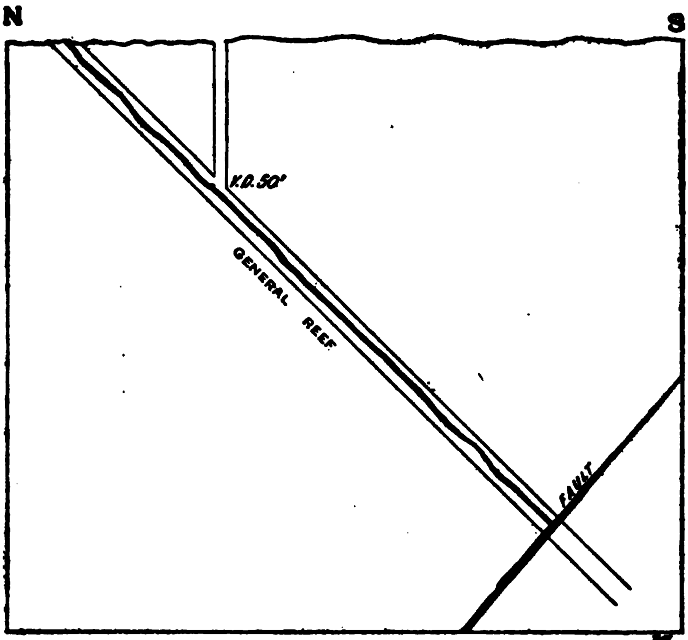
HOMEWARD BOUND, G.M.L. 613.—This lease embraces a portion of the ground embraced by the old Homeward Bound Lease, G.M.L. 579.

There is one fairly large-sized reef cropping out near the northern portion of the property, and trending generally north and south with an east and west arm. This reef is almost flat.

Upon the old Exhibition, G.M.L. 286, which includes the northern portion of the Homeward Bound, little else than surfacing seems to have been done.

Upon the greater portion of the western half of the Homeward Bound, lie all the old "Rejected" workings. Several shafts have been sunk, and much surface work done by previous owners upon an interrupted line of reef, which has a southerly underlay and a general east and west strike.

FIG. 14.



SECTION ACROSS THE GENERAL REEF MARBLE BAR.

The reef is said to lie fairly flat and with an average thickness of about 12 inches, with, however, big bunches here and there.

An underlay shaft had been sunk on the reef to a depth, on 17th September, 1896, of 50 feet on a good body of stone.

The Rejected No. 1 Reef (on old G.M.L. 84) does, however, appear to be upon exactly the same line as that just described. The reef outcropping has been worked by a main vertical shaft 40 feet in depth, which, up to the end of September, 1896, had been continued on the underlay for a further distance of 81 feet. Two reefs are said to have been exposed in the workings, separated by a horse of country. The lower reef is said to have possessed good, well-defined walls, which had an underlie of about 35 degrees to the south. The upper reef, reputed to have been the most regular of the two, had an average thickness of about two feet. Near the foot of the underlay shaft, the reef varied from 18 inches to five feet in width.

So far as can be ascertained from the official figures, the yield of the reefs on the present Homeward Bound Lease appears to have been as shown in the following table:—

Table showing the Yield of the Homeward Bound Reef.

Year.	Name of Lease.	Ore crushed.	Gold therefrom.	Rate per ton.	Total Ore crushed.	Total Gold therefrom.	Average rate per ton.
		tons.	ozs.	ozs.	tons.	ozs.	ozs.
Previous to 1897	Rejected, G.M.L. 105 ...	1,208·00	1,827·00	1·51			
1897 ...	Do. do. ...	65·00	67·00	1·03	1,273·00	1,894·00	1·48
1898 ...	Homeward Bound, G.M.L. 615	249·75	261·15	1·04			
1901 ...	Do. do. ...	198·75	242·25	1·22			
1902 ...	Do. do. ...	7·00	22·90	3·72	455·50	526·30	1·15
	Total				1,728·50	2,420·30	1·40

Shamrock, G.M.L. 160.—An old six-acre lease upon which a fair amount of work must have been done at one time or another. Near the north-eastern angle of the lease is an underlay shaft put down to a depth of 100 feet, on the reef outcropping on the crown of the hill. This reef was intersected by a vertical shaft, No. 1, and farther south-west by shaft No. 2, at depths of which there is no precise information. A third shaft had been sunk at a point 35 feet west of No. 1 to a depth of about 30 feet, but no particulars are available beyond the fact that a quartz reef five inches in thickness had been met with.

The following is a list of the crushings from this property, so far as are disclosed by the official statistics:—

Table showing the Yield of the Shamrock Reef.

Year.	Ore crushed.	Gold therefrom.	Rate per ton.
	tons.	ozs.	ozs.
1895	52·25	120·10 *	2·29
1896	8·00	22·70	2·83
Total	**60·25**	**142·80**	**2·37**

* Includes 33ozs. from unknown tons.

True Blue, G.M.L. 157.—An old six-acre lease adjoining the Shamrock on the east. A considerable amount of open cast work has been carried out. The northernmost shaft on the lease is an underlay shaft 90 feet in depth, connecting with a vertical shaft 24 feet in depth, which had been continued for a further distance of 24 feet on the underlay of the reef. The reef averages two feet in thickness, and underlays about 30 degrees to the south-west. There

is another parallel reef below this one, which attains a thickness of about two feet.

The figures in the table below give the result of the crushings, so far as may be gathered from the official records :—

Table showing the Yield of the True Blue Reef.

Year.	Ore crushed.	Gold therefrom.	Rate per ton.
	tons.	ozs.	ozs.
1893	*	61·20	...
1894	35·50	42·00	1·18
1895	92·50	168·82	1·82
1896	55·25	38·00	·68
Total	183·25	310·02	1·69

* Unknown.

Marble Bar, G.M.L. 288.—An old twelve-acre lease adjoining the Coongan Star Extended on the north, from which in the year 1898, 11 tons of ore yielded 15·70ozs. of gold, thus giving an average of 1·42ozs. of gold per ton.

Coongan Star, G.M.L. 92.—Upon this six-acre lease a good deal of *bonâ fide* work has apparently been done in times past upon a north and south reef, inclined at a very low angle to the west, but which makes no very pronounced outcrop on the surface. An old disused main shaft has been put down upon the summit of a low hill, and the reef worked out about 50 or 60 feet on the underlay.

A vertical shaft had been put down to a depth of 20 feet at a point 150 feet from the summit of the hill, but no particulars are obtainable respecting it.

Adjoining this is another 25 feet in depth, from the bottom of which a drive had been put in 40 feet to the south-east, whilst a third shaft near by had been sunk to an unknown depth. In addition to these old workings is a vertical shaft 33 feet in depth, at which point the reef is met with; this has been followed on the underlay for a further distance of 37 feet. About 100 tons of quartz have been raised and awaited crushing.

Table showing the Yield of the Coongan Star Reef.

Year.	Ore crushed.	Gold therefrom.	Rate per ton.
	tons.	ozs.	ozs.
1894	184·50	310·15	1·68
1895	75·50	131·80	1·74
1896	71·25	157·00	2·20
Total	331·25	598·95	1·80

Coongan Star Extended, G.M.L. 287.—Near the south end of the lease, adjoining the south-east angle of the Coongan Star property, a shaft 25 feet deep had been put down upon a small but good quartz vein, from which a small trial crushing is asserted to have yielded an average of about 2ozs. per ton.

A quartz reef in granite country outcrops near the north-west angle of the lease, but no work appears to have been done upon it. A water shaft of unknown depth is to the west of the reef.

Augusta, G.M.L. 615.—This lease, as at present constituted, embraces by far the larger portion of what was originally included in the Stray Shot, G.M.L. 3, the Excelsior, G.M.L. 21, and the Augusta, G.M.L. 7.

The Augusta reef makes a fairly distinct and well marked outcrop on the surface; the reef, however, has been interrupted near the southern angle of G.M.L. 280, by a north and south fault, which has but a slight throw.

The outcrop of the reef is traceable all round the north-east, east, and south-east sides of the hill, and averages about three feet in width, it extends westwards as far as the Stray Shot, where it is worked by several shafts. There seems, however, good reason to believe that the reef in the Surprise Lease, G.M.L. 167, adjoining the Stray Shot on the west, is the continuation of the Augusta, interrupted, however, by a small fault, lying parallel to that alluded to above. Along the eastern outcrop of the main Augusta reef stone has been broken out in several places.

The Augusta Reef has been worked by a main shaft which has been carried down on the underlie of the reef which is very flat for a considerable distance.

At the 75 feet, 150 feet, and the 266 feet levels drives have been put in for varying distances, but in the absence of an adequate plan of the mine any intelligible description of the reef underground is well nigh impossible, more especially as the majority of the workings are inaccessible.

Overlying the reef is a dyke [5819] of a fine-grained rock, which, under the microscope, seems to consist principally of felspar and an altered dichroic ferro-magnesian constituent.

In the underlay shaft at the 75 feet level the main Augusta Reef is said to have attained a maximum thickness of seven feet, but in the lower levels of the mine it averages only about 12 inches. It is stated that where the reef is wide the good stone is confined to certain bands, chiefly, however, of highly-mineralised bands; in the lower levels of the mine, where the reef is smaller, most of the stone is said to have been worth crushing.

The main Augusta Reef extends right through the Excelsior and the Stray Shot, below the level of the Stray Shot Reef. A great number of shafts have been sunk at relatively short distances apart on the slope of the hill and a considerable amount of surface

work done. The quartz is of a darkish hue, and contains relatively small quantities of the sulphides of iron, copper, and lead.

Table showing the Yield of the Augusta, Stray Shot, and Excelsior Reefs.

Year.	Ore crushed.	Gold therefrom.	Rate per ton.
	tons.	ozs.	ozs.
Previous to 1897	3,349·00	9,219·00 *2,082·00	2·75
1897	1,661·70	1,818·28	1·09
1898	291·70	363·49	1·24
1899	230·00	322·40	1·40
1900	72·00	30·96 †195·00	·43
1901	15·00	26·60	1·77
Total	5,619·40	‡11,780·73	2·09

* From unknown tons. † From tailings. ‡ Does not include ounces from unknown tons and from tailings.

Sundry Claims from the District generally.—In addition to the yield of the reefs described above, there are several others which it is impossible to specify and the returns from which are given in the table below:—

Table showing the Yield from Sundry Claims, Marble Bar.

Year.	Ore crushed.	Gold therefrom.	Rate per ton.
	tons.	ozs.	ozs.
1897	94·50	119·17	1·26
1898	206·00	444·15 *1,000·00	2·15
1899	104·30	244·62 *1,770·00	2·34
1900	15·00	14·00	·93
1903	24·00	24·00	1·00
1904	...	†916·35	...
Total	443·80	‡845·94	1·90

* Alluvial. † Alluvial and dollied. ‡ Does not include alluvial and dollied.

It is, however, not quite clear from the manner in which the returns are presented whether or not these sundry claims include the yield from reefs in other centres not embraced within the limits of the Geological Map of Marble Bar.

Synoptical Table showing the Yield of the Marble Bar Reefs up to the end of 1904.

Name of Reef.	Ore crushed.	Gold therefrom.	Rate per ton.
	tons.	ozs.	ozs.
Augusta	5,619·40	14,057·73	2·50
Augusta No. 1 South ...	66·00	149·60	2·26
Coongan Star	331·25	598·95	1·80
Excelsior	Included under Augusta.		
General	Included under Homeward Bound.		
Homeward Bound ...	1,728·50	2,420·30	1·40
Ironclad	2,040·50	1,441·57	·70
Ironclad South	61·00	24·00	·39
Iron Duke	40·00	25·70	·64
Keep-it-Dark	32·50	73.65	2·26
Marble Bar	11·00	15·70	1·42
Pillendinnie	1·00	342·00	342·00
Rejected	Included under Homeward Bound.		
Robert Bruce	112·00	116·92	1·04
Shamrock	60·25	142·80	2·37
Stray Shot	Included under Augusta.		
Sundry Claims	443·80	4,532·29	10·21
Trafalgar	30·00	90·00	3·00
True Blue	183·25	310·02	1·69
Total	10,760·45	24,341·23	2·26

General.

In the latter end of last year, while in the North-West, a communication was received from Mr. J. Isdell, M.L.A., the Parliamentary representative of the district, containing a request that the tailings in the Marble Bar District be experimented upon by the Department, with the view of suggesting a method by which the large quantity of gold reported to have been lost in previous years could be recovered.

In accordance with instructions, attention was devoted to the question while at Marble Bar, and the heap of accumulated tailings at (*a.*) the Ironclad Mine, and (*b.*) on M.A. 1, were sampled by myself and Mr. Talbot, the Field Assistant.

These, on being received in Perth, were dealt with in the official laboratory, and reported on by Mr. E. S. Simpson, as follows :—

"The following are the results of extraction tests made on two samples of tailings collected by you at Marble Bar :—

"G.S.L. 687, Ironclad Mine.—These tailings consisted mainly of quartz sand, with a small percentage of clay and iron oxides, a very small amount of pyrites and a minute trace of copper. No antimony was present. The samples carried 28 per cent. of slimes. Percolation was easy and rapid. Cyanide consumed 0·63 lbs. per ton. Assay value of tailings, 4dwts. 15grs. per ton; of residues, 1dwt. 9grs. per ton. Extraction, 70·3 per cent. after three days leaching.

"There are no metallurgical difficulties whatever in the way of treating these tailings by the cyanide process. The question of their successful treatment resolves itself into one of economics solely, viz., whether or not 13s. 9d. (the value of the gold which it is possible to extract) will, under local conditions, do more than pay for the cost of extraction.

"G.S.L. 688, M.A. 1.—These tailings also consist mainly of quartz sand, with a small percentage of clay and iron oxides, a trace of pyrites, a slight trace of antimony, and copper carbonates equal to 0·15 per cent. of copper. The sample contained 28 per cent. of slimes. Percolation was very good. Cyanide consumed was very high, viz., 4·19lbs. per ton, probably owing to the copper present. Assay value of tailings, 3dwts. 6grs. per ton; of residues, 1dwt. 22grs. per ton. Extraction 41·0 per cent., after three days leaching.

"It would appear to be impossible to treat these tailings successfully. In the first place they are not rich in gold; in the second, the copper present causes the extraction to be very low, and the consumption of cyanide so high as to be prohibitive."

INDEX TO NAMES OF PLACES, MINES, REEFS, Etc.

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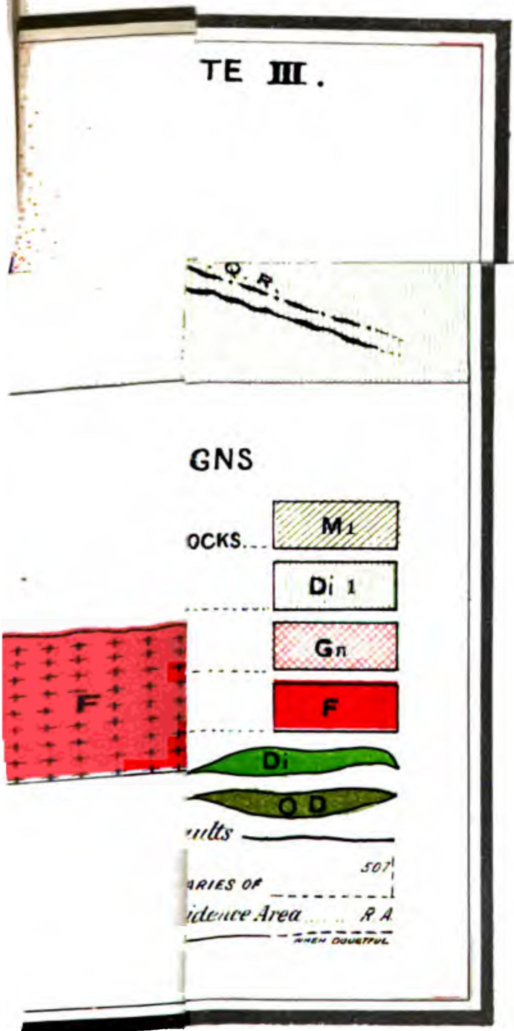
BULLETIN Nº 20 PLATE II.



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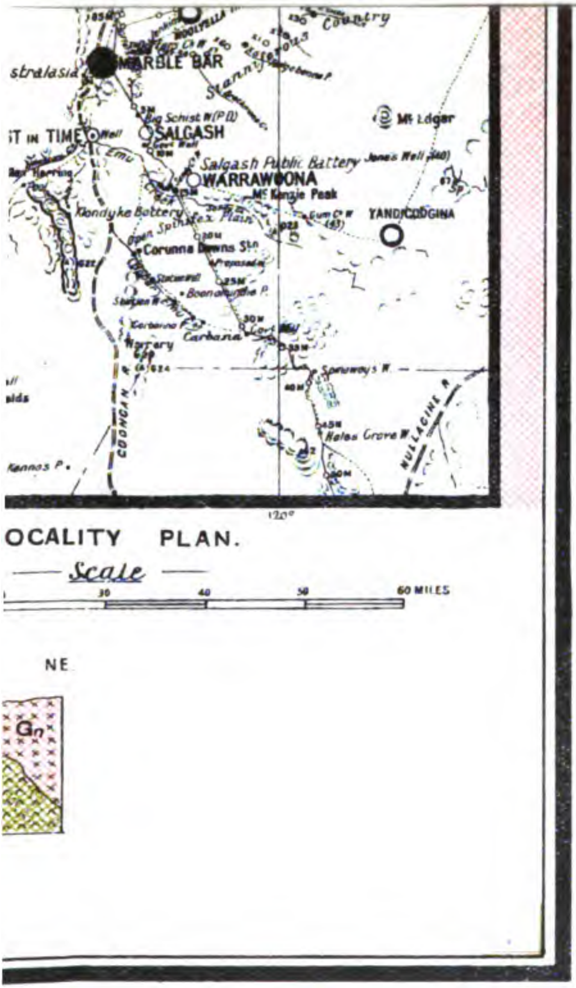

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WESTERN AUSTRALIA.

GEOLOGICAL SURVEY.

BULLETIN No. 21.

THE GEOLOGY AND MINERAL RESOURCES OF THE NORSEMAN DISTRICT, DUNDAS GOLDFIELD,

BY

W. D. CAMPBELL,

Assistant Geologist.

Issued under the authority of the Hon. H. Gregory, M.L.A., Minister for Mines.

WITH A TWO-SHEET GEOLOGICAL MAP, FIVE PLATES, AND 19 FIGURES.

PERTH:

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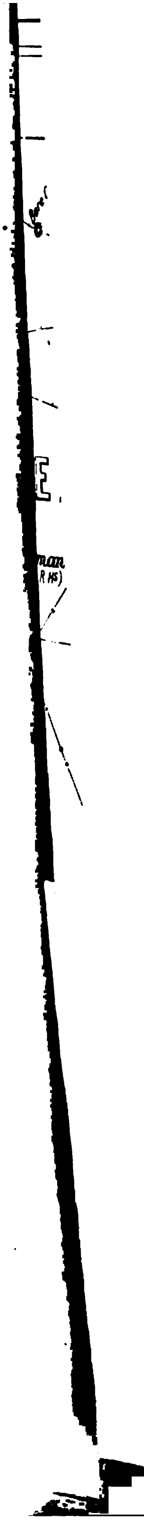

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GEOLOGICAL AND TOPOGRAPHICAL MAP IN TWO SHEETS.

PREFATORY NOTE.

IN consequence of a Parliamentary motion, instructions were issued to the Department, towards the close of the session of 1903, to prepare a topographical map of Norseman. Later on further instructions were sent out to the officer entrusted with the work to combine both geology and topography, as it seemed that what was actually required in the public interest was rather a plan, illustrated by cross sections, showing the trend, extent, and structural relations of the ore deposits and the enclosing rock masses, than mere surface features, such as the Parliamentary motion implied.

The work, which was entrusted to Mr. W. D. Campbell, Assistant Geologist, covers an area of about 46 square miles, embracing so far as is at present understood the productive area of Norseman.

The Map of Norseman, which contains, in addition to the necessary geological and mining information, contours 10 feet apart in altitude, all prominent landmarks, such as hills, shafts, batteries, etc., and should on this account prove of considerable general utility. It may be noted that the construction of topographical maps, which is the necessary basis for all geological work, in important mining districts, consumes an ever-increasing share of a geologist's time, which could well be more profitably employed in many other directions.

The mining plans and sections, of which there are five, together with twelve cross and longitudinal sections, mark an advance on any of the official mining plans yet issued of the Goldfields of the State in that their most prominent features are the lodes (which are as far as possible shown in their relative dimensions), the faults traversing them, and the dykes by which certain of the workings are riddled, rather than the levels, winzes, etc. These data, coupled with the descriptions given in the report, and the various tables of statistics by which it is accompanied, will, it is hoped, form a permanent record of the mines of Norseman up to the date the text was drawn up.

The present report embraces not only the work of Mr. W. D. Campbell, but includes a brief *aperçu* of the labours of other observers.

That portion of the Dundas Goldfield embraced by Mr. Campbell's work consists essentially of a series of metamorphic sedimentary rocks, estimated to reach a thickness, making due allowance for repetition by folding, of not more than 800 feet, which occupies a strip of country skirting the west side of Lake Dundas, and near the west side of Lake Kirk. Some of these ancient sediments appear, according to Mr. Campbell's observations, to have been permeated by secondary silica and oxide of iron, and are now in places represented by the bands of laminated quartzite and the very ferruginous jaspers, which make a pronounced feature in the field. These silicified bands have been indicated by a separate colour and symbol on the Geological Map.

Associated with the metamorphic sedimentary rocks (some of which are conglomeratic) is a large area of what Mr. Campbell has designated as amphibolite, and which appears to be interbedded with the former; as some of these are distinctly amygdaloidal, there seems very good reason for believing them to be ancient lava flows.

In addition to these amphibolites are a series of diorites and epidiorites, which seem to be interbedded with the sedimentary rocks and amphibolites in such a way as to suggest the possibility of their being intrusive sills and dykes. It has not, however, been found possible to separate the latter from the amphibolites on the Geological Map, hence all have been distinguished by the same colour and symbol.

There are also relatively small areas of mica and chlorite schists occurring in the field. These, which it has not been found possible to distinguish by a separate colour and symbol on the Geological Map, may possibly owe their origin to the transmutation of those igneous rocks which make up the larger portion of the surface of Norseman.

Another very important feature is the occurrence of a large number of quartz porphyry dykes which traverse the whole of the area mapped in a general north-east and south-west direction. They vary much in colour, are sometimes fissile, pyritous, and occasionally slightly auriferous. These porphyries, so far as has been observed, traverse all the formations developed on the field other than the metamorphic sedimentary rocks and the very persistent norite dyke which traverses the central portion of the area mapped in a general east and west direction. In all probability

these porphyry dykes form the apophyses of the large granite mass which lies to the east of, and just outside, the limits of the area mapped.

There are in addition a few isolated veins and dykes of dolerite, one of which is seen crossing the reef at the 145 feet level in the main underlay shaft of the Cumberland Gold Mine.

The newest igneous rock on the field is the intrusive norite which forms an east and west range, varying from a mile to half a mile wide, and of which Trig. Hill B 23, near Princess Royal township, forms a part. This dyke extends in an uninterrupted line to North Norcott, about twelve miles to the eastward and for a considerable distance further, whilst to the westward it crosses Lake Cowan and extends far beyond the limits of the area mapped. This dyke appears to have no effect upon the gold contents of any of the quartz reefs it traverses, and, further, is not traversed by any quartz veins.

These older basic and acidic rocks of Norseman are very similar in their character to those which are largely developed in other portions of the Eastern Goldfields; and although the Norseman district affords no direct evidence as to their geological age, there seems very good reason to believe that they all form part of one and the same series.

The earliest observer in the district, Mr. S. Göczel (a former member of the Geological Staff), indicates on his geological sketch map of the Auriferous Region of Western Australia, the greenstones and allies of Norseman as being of Palæozoic Age, whilst the micaceous and talcose schists of the same district are referrred to the Archæan. Much more detailed work, however, in other portions of the State will be required before the age of these rocks can be definitely made out.

Two small fragments of a once more extensive formation occur on the western bank of Lake Cowan, near the John Bull Lease, and four small outliers south of the Queen of the West Reefs, near Lake Dundas. The formation, which at present occupies but a small area, consists principally of a dolomitic limestone with liceous bands. The beds, which contain specimens of *Turritella*, *ecten*, *Cardium* (or *Cardita)*, *Margellania*, and fragments of *olyzoa*, are in all probability of comparatively recent geological re, and may possibly represent the inland extension of the strata iich fringe a portion of the southern coastline of the State.

A very large portion of the Norseman District is occupied by ent superficial deposits, which, in the bed of Lake Cowan, attain

a thickness of at least 377 feet. A very large development of laterite occurs over that portion of the field which is occupied by the ferruginous jaspers, etc.

Norseman has proved a good mining field, the auriferous quartz reefs being scattered over a very large extent of country. The quartz reefs trend generally north and south, and underlie easterly at an angle of about 45 degrees; those trending generally east and west underlie south at angles varying from 60 to 70 degrees. With one or two notable exceptions, the quartz reefs are mostly short and consist chiefly of white quartz with a relatively small proportion of pyrites, galena, with (in certain localities) scheelite and bismuth. Many of the reefs evidently carry rich chutes of gold.

Up to the end of 1904 the area embraced by Mr. Campbell's work has returned 266,004ozs. of gold, or at the rate of 1,019ozs. for every ton of ore treated. From the returns given *in extenso* in the report, it appears that from:—

	Ore crushed.	Gold therefron.	Rate per ton.
	tons.	ozs.	ozs.
Reefs in the Greenstone ...	237,508·47	238,210·52	1·003
Reefs in the Metamorphic Rocks	23,505·63	27,794·08	1,182
Total	**261,014·10**	**266,004·60**	**1·019**

The recent superficial deposits in the Norseman District have yielded only a limited amount of alluvial gold, the total reported from 1899 to 1904 being 1,662·37ozs. In that portion of the report which deals with the mines (and which forms by far its greater bulk) the arrangement and description by lines of reef has been adopted, and the statistics prepared accordingly. The compilation of the Statistics of the Gold Yield has proved unusually troublesome, owing to the number of short-lived leases and quartz claims, in addition to the difficulty of identifying the localities from which the various small parcels of ore were obtained. In their present form, however, they give as complete a record of the gold yield of the different lines of reef at Norseman as is possible.

The report, with its accompanying maps and plans, was, on being submitted to the Minister for Mines, ordered to be printed for public information.

A. GIBB MAITLAND,
Government Geologist.

Geological Survey Office, Perth,
15th March, 1906.

The GEOLOGY and MINERAL RESOURCES of the NORSEMAN DISTRICT.

Introduction.

The area comprised in the accompanying geological map of Norseman is that portion of the Dundas Goldfield lying between the southern end of Lake Cowan and the northern end of Lake Dundas, about eleven miles in a north and south direction and six and a half east and west, with the town of Norseman as a centre; it covers about 46 square miles, excluding the lake plains. The scale of the map is 20 chains to an inch, which is the smallest admitting of the essential details being shown. The map comprises contour lines, or lines of equal altitude at intervals of 20 feet, existing and extinct gold-mining and mineral leases, shafts and their depths where ascertainable, batteries, existing and proposed lines of communication, such as roads, railways, cycle tracks, and telegraphs, water rights, wells, tanks, and pipe lines, business and garden areas, as well as miners' homestead leases, together with the geological boundaries, in addition to the strike and underlay of reefs and dykes. The map is accompanied by an east and west section on a scale of 20 chains to an inch, in addition to the plans and sections of certain of the mines which have been reproduced on a scale of 100 feet to an inch.

The contours have been laid down by a combined tacheometrical and barometrical survey, in order to obtain the greatest expedition with accuracy.

The existing leases shown on the plan are those which were in force at the end of July, 1905, while the statistics of gold yield dealt with in the following report are up to the end of the year 1904, when the total yield of the whole Dundas Goldfield from mining was 247,560·26ozs. of fine gold and 3,162·88ozs. of fine silver from 283,106·38 tons of ore, or ·874ozs. of fine gold per ton, in addition to which the alluvial deposits yielded 1,662·73ozs. of fine gold. The total yield of gold tabulated in detail in this report is 266,004 gross ozs. from 261,014 tons of ore, a yield of 1·019 gross ozs. per ton, comprised as follows:—238,210·52ozs. from 237,508 tons of ore from reefs in the amphibolite area, a yield of 1·003 gross ozs. per ton, and 27,794·08 gross ozs. from 23,505·63 tons of ore from the banded quartzites and ironstone area, a yield of 1·182ozs. per ton. These latter figures represent the product of the reefs, etc., occurring in the area included in the accompanying geological map.

The total quantity of alluvial gold for the year 1904 is given by the Statist of the Mines Department as 109·91ozs. of fine gold, which, divided by the constant ·8419 (*see* table 6 of the 1903 Report f the Department of Mines), gives 130·55 gross ozs., which, ıded to the 6,799·12 gross ozs. of alluvial gold reported up to e end of 1903, makes the total 809·67 gross ozs. of alluvial ıld from this field, or practically from the area mapped.

The compilation of the statistics of gold yield for the mines section have proved unusually troublesome owing to the number of short-lived leases and quartz claims, the majority being held by small parties of miners. There has been a difficulty also in identifying the localities from which the various small parcels of ore have come, in consequence of insufficient description, also the incompleteness of some of the older returns.

History.

The first indications of gold in the Dundas district were discovered by Mr. William Moir, of Fanny's Cove, in July, 1892, while searching for pastoral country. This gentleman found a few specks of gold in the alluvium of a small gully flowing into the west side of Dundas Lake. Mr. Moir, along with Mr. Thomas Stennett, organised a prospecting party to follow up this find, but failed to discover payable gold. It is interesting to note, by way of comparison, that it was in the following month of the same year that Messrs. Bayley and Ford reported gold at "Fly Flat," near the aboriginal rock-well "Coolgardie."

About the same time several other parties also started to prospect the Dundas Hills, which had been so named by Mr. Surveyor General Roe, in 1846. Of these parties, W. Mawson and R. Kirkpatrick were the first to discover an auriferous reef, which they called the "Maybell." This was at the south end of the Dundas Hills, and they obtained, at Southern Cross, a protection area, No. 293, which is identical with Dundas Reward Claim No. 1. Soon after the discovery of this reef, Bromley, Mason, and Desjarlais found a rich outcrop which they named the "Great Dundas," whilst Brodie, Kirtly, and Devine also discovered the "Scotia."

As these localities proved to be about ten miles outside the southern boundary of the Yilgarn Goldfield, which passed east and west about two miles southward of the highest hill (Woolyeenyer) in the district, a new goldfield called Dundas was therefore proclaimed on the 31st of August, 1893. This new goldfield comprised a strip about 50 miles east and west, and about 20 miles north and south along the south side of the Yilgarn Goldfield. The initial point of the description is Mt. Deans, the position of which was at that time thought to be nearly ten miles further south than it really is. The estimate of the area by Mr. H. P. Woodward, the then Government Geologist, who was appointed temporary Warden of the Dundas Goldfield, was 1,000 square miles. A few allotments for the site of the first township, Dundas, were laid out by Surveyor W. H. Angove, in 1893, adjacent to the Noganyer Soak.

Mr. Woodward was succeeded in January, 1894, by Mr. Arthur Hicks.

On the 6th of April, 1894, the south boundary of the Yilgarn Goldfield was altered to about 25 miles further north; and the Dundas Goldfield was given a length, east and west, of about 172 miles by 93 miles wide, the area being thus increased to about 15,996 square miles.

A discovery of a gold-bearing reef towards the northern end of the same ranges, between Lakes Cowan and Dundas, was made in July, 1894, by L. Sinclair, which he named the "Norseman." Another reef, the "Mt. Barker," was also found by Ramsay and party, who took up their lease on the 13th of August, the same time as Sinclair and party took up the "Norseman." These finds were followed by others, and the southern end of the field was eclipsed by what was known at first as North Dundas. The Mt. Benson was taken up by A. E. Stehn and party, on 23rd October, 1894, and the Lady Mary by Geo. Prout, on behalf of Geo. Brookman, on the 30th November following, and the Princess Royal by F. G. Chester and party, on 2nd May, 1895.

In consequence of this shifting of the population, the principal town, Norseman, was laid out about 15 miles north of the first townsite (Dundas), on the 29th of April, 1895. Both were gazetted on the 24th May, 1895, Norseman being further proclaimed a municipality on the 17th January, 1896.

On the 20th March, 1896, the description of the boundaries of the goldfield was altered, but apparently not the boundaries themselves, beyond excluding all townsites and fee simple lands within those boundaries; and in July following, the Warden's office was moved to Norseman from Dundas, although business had to be carried on until the end of the year in tents. On the 6th of May, 1896, the Coolgardie-Eucla *via* Norseman telegraph line was opened, and Messrs. Cobb and Co's. coaches began running to Coolgardie and to Esperance, a bi-weekly mail being established in August, 1896.

In May, 1899, Mr. P. L. Gibbons succeeded as Warden. On the 22nd of August, 1902 the width of the goldfield north and south was reduced to about 66 miles, making the area 11,500 square miles. This proclamation took effect from September, 1902, the description being:—

"Commencing at the south-east corner of the Coolgardie goldfield, thence east about 42¼ miles, thence south about 66 miles, thence west 173 miles, passing through the 75-mile post on the Dundas-Esperance road, thence north about 66 miles to the south-west corner of the said Coolgardie goldfield, thence east about 132½ miles along the southern boundary to the starting point."

These boundaries exist at the present time.

In March, 1905, Mr. L. L. Crockett, the present Warden, succeeded Mr. Gibbons.

The population, according to the census of 1901, was 1,593, viz., 1,165 males, and 428 females. At the end of 1904, it is estimated that the population was 1,600, viz., 1,090 males, and 510 females.

There were 88 gold-mining leases in force at the end of the year 1904, with an area of 913 acres; of these only one, the "Break-o'-Day" of 24 acres, was outside the limits of this map, and of these 88 leases there were 46 held by companies and 42 by individuals.

A view of the town of Norseman appeared in the Report of the Department of Mines for the year 1900.

The following table gives the yield of the whole field up to the close of the past year, as shown (*a*) by the figures furnished to the Department of Mines, and (*b*) the Customs Authorities and the Perth Mint; this discloses the fact that 49,204·45 gross ounces have not been reported to the Department for reasons best known to the delinquents. The alluvial workings have not been extensive enough to have contributed much of this discrepancy. The 172 quartz, claims and 30 or more unregistered quartz claims, may have obtained a few hundred ounces of gold by dollying, but the bulk of the amount could hardly be materially affected thereby. While not venturing any further opinion on the matter, it is impossible not to recall to mind that there is lamentable and demoralising widely spread opinion among miners throughout the Eastern goldfields that the gold in any of the mines is as much the property of the miner, who is paid to work therein, as of the Company which employs him.

Yield of Gold from the Dundas Goldfield.

Year.	Ore crushed.	Gold therefrom.	Gold exported and received at Perth Mint.	
			Gross weight.	Fine contents.
	tons	ozs.	ozs.	ozs.
1893 ...	3,020·00 (1893–1896)	a 3,663·25 (1893–1896)	147·97	132·37
1894 ...			228·38	204·31
1895 ...			241·90	216·40
1896 ...			4,350·31	3,891·77
1897	16,882·98	b 17,115·65	19,310·81	17,275·36
1898	30,928·35	c 32,469·59	32,031·82	28,655·52
1899	59,379·30	d 37,839·28	45,164·95	40,404·36
1900	49,014·50	e 34,036·83	40,687·56	36,398·91
1901	38,373·00	f 29,843·03	38,796·25	35,163·62
1902	26,123·75	g 28,579·34	36,210·99	31,115·47
1903	25,953·00	h 33,845·76	41,553·90	35,217·41
1904	33,431·50	i 31,830·27	39,702·61	33,181·09
	283,106·38	**249,223·00**	**298,427·45**	**261,856·59**
			249,223·00ozs.	
Amount of gold not reported			49,204·45ozs.	

a Details not available. Prior to 1893 included with Yilgarn.
b Includes 68·42ozs. dollied and specimens.
c „ 4·94ozs. „ „
d „ 125·10ozs. „ „ and 122·17ozs. alluvial.
e „ 31·24ozs. „ „ „ 137·63ozs. „
f „ 143·83ozs. „ „ „ 502·02ozs. „
g „ 953·84ozs. „ „ „ 358·01ozs. „
h „ 691·94ozs. ore crushed and dollied (39,669·86 tons) and 424·04ozs. alluvial
i Includes 1,127·68ozs. dollied and specimens and 118·50ozs. alluvial. There was also 3162·88ozs. of silver obtained from ore.

Topography.

The area comprised in the map varies in height from about 845 feet to 1,580 feet above the sea level, and about one-half consists of well-wooded ranges of hills, trending slightly east of north. The principal exception occurs southward of the Princess Royal township, where there is a due east and west ridge. The height of the bed of Lake Cowan is 685 feet, while that of Lake Dundas, eastward of the Norseman Government tank, is about 20 feet lower than Lake Cowan. The wooded hills and extensive lake flats give a very varied appearance to the landscape (Figs. 1 and 2). The western shores of the lakes are mostly steep and rugged, while the eastern are mostly gently sloping ground. These lakes are dry during the greater part of the year; but in the driest seasons there is moisture at 3 or 4 inches below the surface in their central portions, the evaporation of which is the cause of the very conspicuous mirages that are continually to be seen during the warm portion of any bright summer day. Blown sand ridges and banks composed of fine particles of gypsum and sand are of frequent occurrence on the eastern borders of the lakes, and carry a scanty vegetation ranging from the so-called samphire plant (*Salicorina arbuscula*) to occasional gum trees up to about 20 feet in height.

The east and west ridge already mentioned is mostly covered with spinifex and a few scattered shrubs. This paucity of vegetation is caused through the scanty and silicious soil produced by the decomposition of the norite rock, being unsuited to the growth of trees. Almost all the other hilly country has an open bush composed of salmon gum, white gum, blackbutt and morell, ranging up to 2 feet in diameter. The whole of this is being gradually cut down for firewood and mining purposes, and unfortunately often in a very wasteful manner, many of the larger butts of the trees being abandoned instead of being split up, a practice which the purchase of timber by weight instead of by measurement would diminish greatly. It is satisfactory to see that the growth of the naturally sown young trees, judging by some of those tracts that have been worked over or had forest fires on them, appears to be over one foot per year.

The hills are rounded in outline, except along the banded quartzite and ironstones near the west side of Lake Dundas and Lake Kirk; there the ridges are steep and rugged, intersected at intervals by narrow gullies, with huge boulderlike outcrops of the banded rock; the tops of these ridges and spurs have, in places, rugged masses of laterite.

The meteorological observations taken at Norseman from the beginning of 1897 to the end of 1904 show a yearly average of 10·31 inches of rainfall, the lowest being 6·44 inches in 1899 and the highest in 1904, when it was 14·19 inches.

Eight observations were made for magnetic variation and dip by the writer, these are shown on the geological map. In the amphibolite area it ranged from 1·58° west and 21·87° south at

Norseman, to 3·06° west and 25·62° south at Princess Royal, while in the banded ironstone area it varied from 1° west and 21·12° south at the Government Tank to 6·16° west and 19·25° south at the Lady Mary G.M.; at the latter place there is a considerable amount of magnetite in the ironstone. Some samples which the writer found on the east boundary of this Company's ground were sufficiently magnetic to pull the compass needle right round the circle.

Water Supply.

The well water in the district is mostly either brackish or salt, the only exception occurs along the margins of the east and west norite ridge, where potable water has been found at W.R. 167, but the supply is limited. For analyses of this and other samples, *see* Table I., page 118.

The water from W.R. 168 is more saline, but both this and the water from W.R.'s 160 and 146 is used for stock. The reason of the saline character of the subsoil water is explained by Mr. Göczel, in his official report, which is referred to on a later page. The well water being inadequate for either boiler or battery purposes, and the mine water also, excepting that at the Desirable and Three Colonies, endeavours were made in the early period of the mining industry to obtain water from the lakes, as none of the mines were a greater distance than two miles from them, but it has not been found possible to obtain any supply by boring, and only a precarious one by collecting trenches. Trenches are, however, being used by the State Battery, the Mararoa, Cumberland, and Lady Mary batteries. Mr. E. S. Simpson, the Mineralogist and Assayer, discussed the use of brines in gold extraction in the Geological Survey Report for the year 1898 (*see* Table I., page 118).

The upper stratum in these lakes is largely a gypsum sand, but there is usually a clayey bituminous silt below this sand. The Public Works Department put down a bore in Water Reserve 3326, in the Norseman township, previous to 1896 and reached "diorite" at 165 feet; a small quantity of water was met with in this bore, scarcely sufficient to warrant more work being done; however, further prospecting subsequently located a permanent supply of salt water only 50 feet north of this spot, and a well of 127 feet was made which affords a supply of 4,000 gallons per hour. This well has been leased jointly by the State Battery and the Norseman Gold Mining Company.

In September, 1896, a bore was put down on the sand ridge about 35 feet above the lake, and about eight chains east of the edge of the lake, by the New Coolgardie Water Supply Company. Mr. W. C. Burkitt, who was in charge of the boring party, informed me that sand and clay were passed through, and water struck at 58 feet, in a band of ironstained rubble about three feet thick, and then sand and clay again. The country rock was met with at 99½ feet, and the bore was continued into it for seven feet. Another bore was put down in the lake about 17 chains from its edge, and about

29 feet from the edge of the ditch, by the same company. The manager, Mr. A. Mofflin, supplied the Department, in September, 1900, with the following particulars:—

"Sinking was easy, through clayey material for 130ft., when soft rock with pyrites was met with till 175ft. was reached, and then soft bituminous mud, and at 300ft. a pyriteous bed and quartz; at 305ft. it changed to clay with pebbles and very hard slate until quartz was reached at 377ft. Water came within 9ft. of the top of the bore, but this could be readily pumped down, and the company then ceased operations."

The iron casing and plug now mark the spot.

In 1899, the Government constructed a large concrete-lined tank three miles from Norseman, near Lake Dundas, capable of holding 2,853,100 gallons at a cost of £16,955, from which water is pumped up to two iron service tanks near the Valkyrie G.M., from whence a supply pipe extends to Princess Royal, with a branch pipe to Norseman. This has now been found insufficient for the requirements, and auxiliary tanks are contemplated.

Previous Observations on the Geology of the Dundas Goldfield.

A brief reference is made to the goldfield by Mr. H. P. Woodward, the then Government Geologist, in his Mining Handbook to the Colony of Western Australia, published in 1894, p. 77; a second edition of which was published in 1895. He says on p. 111:—

"The auriferous belt is narrow and seems to be the southern extension of the Coolgardie line, but south of this it has not been traced. There are three or four lines of gold-bearing reefs, but the gold-bearing stone rarely outcrops, so that a good deal of prospecting is necessary."

On page 38:—

"The sixth, or second auriferous belt of granites, gneisses, and schists, lies next, and at present its width is unknown, but it is certainly considerable in places, and has been proved, wherever prospected, to be extremely rich in gold. It extends from the Dundas Hills (where this formation first outcrops from below the sand plains) by Wagemulla, Coolgardie, the Three Pinnacles, Ularring, Lake Carey, and following the same line as the other belts and turning with them to the north-west by the Nullagine, Marble Bar, Pilbarra, Egina, and Mallina upon the north-west coast."

About the end of May, 1893, Mr. S. Göczel accompanied a Government survey party in the capacity of Geologist, and made a trip to the Dundas Hills and their surroundings, and from thence *via* Mount Ridley to Esperance Bay, arriving there on the 25th September; his report appeared in the *ad interim* report of the Department of Mines for the half-year ending 30th June, 1894, Appendix 6, p. 36. He considered that the direction of Lake Cowan is along an old break in the Archæan strata; this break extending through Lake Lefroy, Lake Cowan, and the lake south of Dundas.

Mr. Göczel, in his report on "The Central Goldfields of Western Australia," on page 27 of the same publication, says:—

"Of banded rocks the most generally represented on the goldfields are amphibolites—they overlay the gneiss sometimes directly and sometimes beds of quartzite, of syenitic gneiss, of mica, or of hornblende schist occur

between them—the upper strata of the amphibolites appear as chloritic schists. Of the massive rocks the older greenstones (diorites, diabases) and felsite porphyries are best represented. Beds of volcanic tuffs (greenstone and felsite tuffs) are abundant and extensive. Hill ranges, formed of striped ferruginous ribbon-jasper, indicate generally, lines along which breaks and dislocation have occurred. Those jaspers are the product of hydrothermal metamorphosis, over-heated waters, forming part of the eruptive magma, have forced their way into the pores and fissures of the adjoining amphibolites. By means of the introduction of silica, and complete re-crystallization of the original material, the mineralogical constitution of these rocks was completely altered. Those tuffs have been spread over wide areas by the waves of an ancient ocean, they consist of volcanic ashes, sands, lapilli, and the already described volcanic spherulites whose ejection was contemporaneous with the felsite porphry eruptions. In all probability submarine volcanic emissions have delivered their material to the ancient ocean, which, in its turn, has deposited them in the form of beds, following the deviations and depressions of its bottom."

On page 17 he continues—

"We meet with strata of the same section (Archæan), rocks forming basis sometimes overlaid by cappings and beds of ferruginous grits; sandstones and conglomerates which hardly ever attain any considerable thickness. These strata are more prevalent in the northern parts, chiefly in the Lake Cowan country and in the Dundas hills, on a relatively similar level, but at considerably lesser absolute height. In those parts of the country those strata are usually protected by overhanging greenstone formations and show their development in form of quartzite banks, conglomerates, shales, and phyllites. The old greenstones (diorite, diabase, gabbro), including the schistose and banded features (felspar—amphibolites, schists, etc.) form hills and ranges along gigantic breaks in the Archæan strata, they generally also indicate those stretches of country in which gold deposits occur. There can hardly be any doubt that the old greenstones are eruptive rocks of this palæozoic era."

On page 28, he speaks of the primary gold deposits, and attributes a hydrothermal origin to the quartz reefs, and on page 29 classes the lodes as single and compound—

"The latter are simply dykes, sometimes diorite or diabase, but chiefly felsite porphyry, containing small auriferous quartz lodes in their body. . . . . The lodes occurring in the dykes owe their origin to the contraction of the cooling magma, or in some instances to pressure, and the material which now fills them was introduced in solution; the former has usually massive quartz, and the gold occurs in ore columns, or so-called shoots of greater or smaller extent."

In regard to surface deposits he says, on p. 26:—

"The rock decomposes under the atmospheric influences, the schistose and tufaceous country absorbs the falling rain almost immediately, consequently the detritus of decomposition on the flat areas is not removed by surface waters; it often accumulates. The detritus of the country rock being almost entirely removed by wind, a continuous increase of the bulkier fragments takes place. The limit of that accumulation of quartz and ironstone is reached when the surface is covered with them, so that they form a cover of protection for the underlying detritus against the winds. Until that period, the surface of an area subject to such æolian surface accumulations recedes to a lower level, and the accumulated fragments receive in course of time, under the atmospheric influences, rounded and smooth surfaces. From the time when æolian denudation ceases, accumulative decomposition proper takes place; that is, the surface detritus increases at the expense of the underlying decomposing rock. This feature of decomposition is the one most frequently met with on the goldfield."

In regard to the inland salt lakes, he says, on p. 25, that:—

"The salt is from the disintegration of rock forming minerals, with every rain new supplies of salt are carried towards the depressions. Besides chloride of sodium, or common salt, considerable quantities of carbonates, sulphates, and chlorides of calcium, magnesium, sodium, and potassium are dissolved and transported into the lakes. Here evaporation takes place. In water the point of saturation is first reached with sulphate of calcium or gypsum, and only later with common salt. At the beginning of dry weather the shores of the lakes are covered first with glittering crystals of gypsum before the efflorescence of salt appears. The gypsum banks along the shores of lakes gives us an idea of the quantities of material dissolved, transported, and redeposited by the waters. Those gypsum banks which we see are only the more recent products of the above process of nature, and much greater quantities are already buried by lacustrine sediments and loess. As evaporation progresses, salt is deposited at the bottom of the lakes, intermixed with sediments consisting of fine-grained argillaceous sand. The bulk of these sediments is blown by the winds into the lakes. Large areas, forming parts of the beds of shallow salt lakes, are repeatedly laid dry by evaporation, and their salt efflorescences appear on their surface. In dry and windy weather, salt and dust of such dry lake areas are scattered by the winds over the surrounding country, supplying its soil with a considerable quantity of salt. To the salt supplied in this manner, the extension of a saline vegetation far beyond the limits of the lake is due. The more easily soluble salts are deposited only by a complete evaporation, consequently only gypsum and common salt are generally met with."

Dr. Charles Chewings read a paper, entitled "Geological Notes on the Coolgardie Goldfields," before the Royal Colonial Institute on 17th March, 1896. This has already been summarised by my former colleague (T. Blatchford) in Bulletin No. 3 on the Geology of the Coolgardie Goldfield. On p. 5 he speaks of—

"vast beds of conglomerates, interbedded with the schists and slates,"

and on p. 10, in regard to Norseman,

"a great variety of dark-coloured schists and slates and crushed diorite have been here intruded into by the heaviest diorite eruptions I have seen on the field. While the reefs follow a north-south strike as a rule, and underlie in general to the east, this is by no means without exceptions. The country appears to have been much disturbed, and cracks were formed in all directions, and the reefs that now fill them also run in various directions. From what I saw I conclude the quartz reefs, almost without exception, carry gold; many of them are rich. Some are large and others small, and good specimens are occasionally obtained. A railway to this field is badly needed."

A topographical sketch map and geological section of the Norseman district was made and published in 1896, by James Parkinson, F.G.S., on an approximate scale of one inch per mile; this appears from a letter received by the writer from Mr. Parkinson was in the year 1896; the place of publication, however, is not stated. The plan showed a proposed loop tramline and branches, altogether about nine miles in length, extending from Messrs. Bevilaqua and Thompson's battery, which was the first battery erected on this goldfield. The tramline was laid out by Mr. Stirling Smeaton, C.E., and was for a two feet six inch gauge, and most of the earthwork had been made when the scheme fell through.

In the *Geological Magazine*, decade 4, Vol. 4, No. 398, p. 363, August, 1897, there is a paper on "The Dry Lakes of Western

Australia," by H. P. Woodward. He contends that the term "lake" is a misnomer, and that the lakes are merely large clay pans in valleys in high sand plains, and from these valleys rise steep rocky ridges consisting of hornblende schists, diorite dykes, and quartz reefs, which compose the auriferous series and that—

"These valleys form the main drainage of the country, which falls in a south-easterly direction, but so gradually that the rain water, instead of cutting out a channel, spreads out in a broad sheet over the flat surface, thus forming, during a wet season, a series of large but extremely shallow lakes. The beds of these pans are for the most part composed of a thin layer of clay, which rests directly upon the upturned edges of the highly inclined decomposed schists beneath. In other cases the covering of clay is entirely wanting, the floor being apparently formed directly by the planed down edges of the indurated rock."

A pamphlet descriptive of the mines of the "Norseman Gold Belt" was drawn up and published by Mr. Arthur Catlin towards the end of 1899, from visits to the mines made between September, 1898, and March, 1899. His detailed accounts have been of considerable assistance in the present account, and, where used, acknowledgement is made.

Mr. H. P. Woodward also reported on the Dundas Goldfield in 1901, and it appeared on page 15 of the Annual Progress Report of the Geological Survey for that year. He states:—

"There are about three distinct main lines of auriferous lodes, most of which dip at an angle of about 45 degrees, and vary considerably in size and richness. A very considerable amount of development work has been done upon them, and it is difficult to understand why some of them, which are undoubtedly payable propositions, should have been abandoned, whilst in some instances it is strange to find that so much money should have been expended upon such valueless lodes."

Of the former, he mentions the Desirable and No. 1 North Norseman. In regard to the Princess Royal Deep Lead, he says:—

"The wash is a mottled clay, with ironstone nodules and rounded quartz pebbles, whilst the gold is often found in considerable sized pieces. The gutter is 90 feet in width, resting upon a decomposed schistose bottom, the eastern bank of which rises abruptly and the western gradually. This lead must be of considerable antiquity, as the slides that have taken place in the bed rock ore are often continued through the wash itself."

Mr. A. Montgomery, the State Mining Engineer, visited the Norseman district in 1903. His report is to be found on p. 53 of the Division 2 of the Report of the Department of Mines for that year. He refers to a local proposal to test the country between the Norseman easterly reefs and the laminated quartzite series, whose underlay converge together. In the latter formation, he says:—

"The main veins of quartz seem usually to be parallel to the laminations of the quartzite, but the smaller ones are very irregular, and run in all directions through it. The quartz and brown oxide of iron carry some gold, and a good deal of work has been done in consequence, some of it with rather hopeful results. At first sight the impression is that the quartzites and jaspers are a belt of metamorphic rocks originally of sedimentary origin, and it may be that this is correct; but after examination of the very similar occurrence of jasper reefs at Boorara, Kalgoorlie, Edjudina, Erlistoun, and Black Range, I am of opinion that they are much more probably altered portions of the greenstone country, in which laminated structure

has been produced by intense pressure and shearing stress along a line or zone of faulting movement, and that the change of rock to quartzite and jasper has been effected by hydrothermal and pneumatolytic action (*i.e.*, by the action of intensely heated aqueous vapour) removing soluble constituents from the rocks and charging them highly in return with silica and oxide of iron . . . . and pyrites so as to make it now partake of the character of a lode." . . . .

And upon the Lady Mary deep lead he says:—

"Undoubted alluvial material was obtained, containing well water-worn stones, though mostly of a clayey character, and yielding encouraging prospects of gold. One fairly large nugget that had been obtained was shown to me, and was remarkably free from any sign of attrition by being transported by water, showing several sharp crystalline points. A lot of the fine gold was also crystalline and deposited in the faces of small crevices in clayey material and along minute rootlets of trees, which had penetrated down from the surface. The occurrence was quite similar to that of the gold in the well-known "pug" at Kanowna, to which some of the more clayey material bears a very strong resemblance. Some of the gold, however, was of the ordinary "water-worn alluvial character."

He considers the crystalline gold to have been dissolved and re-precipitated.

"With the exception of those in the quartzite belt, which are largely country rock infiltrated and partly substituted by silica, with ramifying quartz veins, the reefs of this district are composed of fairly clean white quartz, with a small percentage of pyrites. In places, however, the greenstone country rock itself has been highly charged with silica, and the values are in dark siliceous material similar to that so common in the lodes of Kalgoorlie. The walls of the reefs have usually well-defined, smoothed and striated surfaces, showing them to have been fissures on which movement of the country took place. They have every appearance of being permanent to any depth to which mining is likely to follow them."

General Geology.

The following table indicates the various geological formations occurring in the portion of the Dundas Goldfield embraced by the Geological Map:—

Superficial Deposits	Ironstone Gravel and Laterite Travertine Gypsum Dolomite.
Crystalline Rock—Amphibolite traversed by	Norite Granite Porphyries Quartz Reefs Felsite and Quartz Porphyries Dolerite Diorite and Epidiorite.

With interbedded

Metamorphic Sandstones and Conglomerates, with Banded Quartzites and Ironstone	Quartz Reefs and Lodes Felspar Porphyries Mica-diorite and Epidiorite.

The surface covering, excepting the hill tops, where the rock is usually bare, is concretionary ironstone gravel, which rests on kaolin in the flatter portions of the district; both result from the decomposition of the amphibolite, which is the predominating rock.

In the neighbourhood of the banded ironstones, the heavier residual particles left after decomposition of that material have re-combined as laterite, or concretionary ironstone [5613, 5967]. This laterite is found in all stages of solidification from stray patches to masses ten or more feet thick, forming cappings and fringes, chiefly on the eastern side of the banded ironstone ridges. It often weathers into boulder-like blocks having a dark rusty red colour, and these masses are often erroneously attributed by miners to volcanic action. Particles of gold are found sometimes in the centre of the ironstone nodules, or scattered throughout its mass; also occasionally fragments and pebbles of quartz, but the ironstone conglomerate does not contain fragments or pebbles of other rocks, being simply a residual concretion.

Kaolinized ground does not cover the country here to anything like the extent and thickness that it does at Kalgoorlie and further north. At the Princess Royal townsite, there is a strip of this material about a mile long and a quarter of a mile wide, which may be either a remnant of a wider covering or be due to the felsite dykes in this locality, being very susceptible to decomposition. In the south end of the patch the deep lead referred to later on was found. No particular age can be assigned to this kaolin, it is probably mostly decomposed rock "*in situ*," and has been increasing in depth as long as this has been dry land.

The alluvium covering the flat slopes of the eastern side of Lakes Cowan and Dundas merge at depths with the lacustrine deposits that fill up these immense lake basins; these deposits consist of dark bituminous silt and clay, which have been proved to have a depth of 377 feet. Some of the valleys and gullies that debouch into Lake Dundas have a considerable depth of kaolin. In the Lady Mary Gully a deep lead has been found, but only of small extent; other smaller gullies on the eastern slope have also gold in shallow gravel.

Associated with the kaolin and decomposed amphibolite rock is a thin calcareous incrustation of travertine, which is a calcareous residue or cement, resulting from the decomposition of the bed rock. This also occurs to a lesser degree on the norite area.

Crystals of selenite can be seen in the lake trenched banks, ranging up to five inches in length, whilst blown gypsum sand ridges are frequent along the south-eastern side of Lake Cowan, where it has accumulated through the action of the prevailing wind:—

The manufacture of salt by forming evaporating pans in the lake beds is quite feasible, requiring only the simplest procedure.

Fig. 3.

Govt. Photo. Litho.

A dozen miners' homestead leases have been taken up in the district during the last year or two, principally for growing wheat for horse feed. The experience in South Australia in districts with a similarly small rainfall shows that wheat growing is very precarious, but dairying is being successfully engaged in. Where the latter has been tried at Norseman it has also been successful. There seems to be a probability, judging from experiments that have been made, that both vines and fruit trees will grow in portions of this district and towards Esperance; the gravelly soil appears suitable.

Mr. E. S. Simpson, Mineralogist and Assayer, has supplied the following results of analyses of two samples of gypsum from Lake Cowan:—

G.S.L.	1568	1602
G.S.M.	5442	6131
Description	Powdery	Lump
Calcium sulphate, $CaSO_4$	67·28 %	64·95 %
Calcium carbonate, $CaCO_3$	3·96	2·10
Total lime, CaO	29·94	27·93

Pure gypsum contains 79·1 % $CaSO_4$.

Neither of these samples are suited for the manufacture of plasters owing to the presence of iron oxide, sand, and other impurities. They could, however, be used for agricultural purposes, for which their applicability in Australia is somewhat limited. Gypsum is chiefly used in agriculture for:—

(*a*.) Coagulating the colloids of heavy clay soils, and thus rendering them more friable and more easily worked. (*b*.) Converting the highly objectionable "black alkali" (sodium carbonate) into a far less harmful sodium sulphate. I do not think any of our land in the State contains an appreciable amount of black alkali. (*c*.) Supplying lime and sulphur, both plant foods, to the soil in a readily assimilable form. The great majority of soils already contain more than sufficient of these substances, whilst more are added in the form of phosphatic manures. (*d*.) Assisting in converting the alkalis of the soil into forms in which they can be readily absorbed by plants. Gypsum of high grade, used in small quantities for metallurgical purposes, is at present, I understand, being landed at the Fremantle smelter for about 15s. per ton.

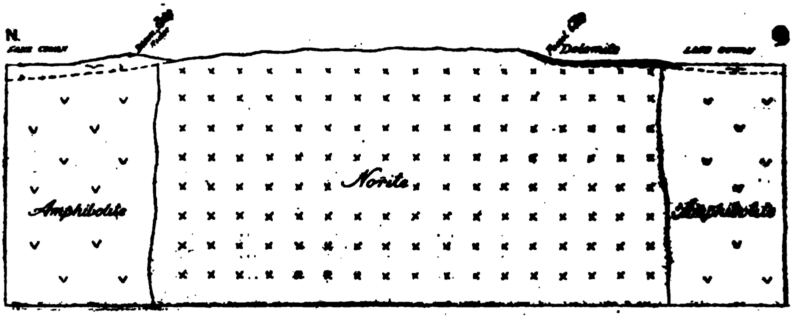
Hillocks and long ridges of dolomite occur north and north-east of Norseman, and on the south margin of the norite rock at the mineral lease No. 1 at Lake Cowan (Fig. 3) and another area near the Israelite Bay track, near Lake Dundas. This last is, however, not within the limits of the map. Near M.L. 1, a portion of the dolomite has been silicified into flinty masses, varying in colour from grey and pale green to black. The dolomite is being quarried and burnt for lime at M.L. 1. It forms only an inferior kind of lime, but it saves the heavy cost of freight that would otherwise be entailed.

It seems most probable that these patches of dolomite have been formed by thermal springs, as they occur in places that are

NOTE.—Since the above was put in type it has been found that a sample of a similar beach deposit [4679] was collected by Mr. J. B. Rankine in the year 1898, on the same side of Lake Cowan but 14 miles in a direct line northerly, and south-east of the Day Dawn, M.L. 129, showing the wide extension of these deposits. -W. D. C.

favourable to such an origin. The only other explanation would be that they are altered sedimentary limestone, through the action of water holding magnesia in solution, but no trace of any bedded character is discernible in the dolomite.

FIG. 4.



SECTION ACROSS NORITE DYKE & FOSSIL BED

About thirty chains north-east from M.L. 1 on the same patch, is a most interesting and as far as the writer is aware, unique opalized remnant of an old sea beach, at about 35 feet above the present level of Lake Cowan containing either late Tertiary or Recent marine shells, such as *Turritella*, *Pecten*, *Cardium* or *Cardita* and *Margellania* and numerous fragments of other shells, *Echinii* and *Polyzoa*; and the author would earnestly suggest that the locality be made a public reserve, so as to preserve this interesting relic from destruction. The best portions where the shells have been weathered out into relief having been, in the past, used for purposes of road construction. This old beach is the one solitary evidence as yet that the southern portion of Western Australia was in recent geological time 900 feet lower than it is now, and it is worthy of the State's protection.

Silicified specimens of what has been determined by Mr. Etheridge, the Curator of the Australian Museum, Sydney, as being true Eucalypti wood, occur on the valley flat of the Mary Cater Gully and on the laterite flat on the north side of Windlas Gully adjacent, both are north of the Israelite Bay track near Lake Dundas. In the latter locality, it occurs in a semi-chalcedonized matrix. This evidence bearing upon the history of Eucalypti in time is interesting.

Mr. Etheridge mentions that—

"McCoy has described definite eucalyptus foliage from the older gold drifts (Pliocene?) of Daylesford in Victoria. Ettingshausen also has described several so called species of Eucalyptus from the upper tertiaries of New South Wales; viz.: Dalton, near Gunning and the main deep lead at the Vegetable Creek Tinfield, New England."

The writer was shown an obsidianite, or volcanic glass button, about $\frac{3}{4}$ inch in diameter, which was found on the surface of Lake Dundas, north of the Narracoorte Gully. Their occurrence is rare in this district.

The extensive tracts occupied by the lakes present an interesting study, and about which very little has been said and known, for until the few bores had been put down here and at Coolgardie, it was supposed that they were only shallow hollows. In W.R. 94 at Norseman, a bore situated about 1,100 feet from the edge of the Lake proved a depth of 377 feet of silt, and at Coolgardie 400 feet (*see* Annual Progress Report of the Geological Survey for 1900, p. 22). In the latter place there could be no outlet for running water at this depth, and there must be there, a rock basin 400 feet deep. Lake Cowan evidently is another rock basin, only of immensely larger extent. A considerable portion of the north part of Lake Kirk has a flat floor of rock that has been planed down horizontally showing the hard upturned edge of rock, with numerous veins of quartz traversing it; the surface is cleanly cut and undecomposed.

In regard to the origin of these rock basins, there is but one agent that could scoop out hollows such as these, and that is ice; in either the form of an ice cap over the whole country or by more local glaciers. This assumption is by no means an improbable one, it would be quite in keeping with the evidence of known ice grooving of rock surfaces in South Australia. There is proof of a great alteration of the level of the land having occurred here in recent geological time, in the old sea beach already described. It has moreover previously been shown that ice worn markings on boulders occur in the Gascoyne Carboniferous conglomerates which indicate glacial conditions (*see* Annual Progress Report of the Geological Survey for the year 1900, p. 28).

The prevailing rounded features of all this part of Western Australia would be quite such a configuration as would be produced by glacial action.

The distribution of the obsidianites over the face of the country appear to be very irregular, and appear to point to other sources of distribution than sub-ærial. That they are volcanic ejecta is self-evident, but their source is still a mystery. The author would suggest that their distribution has been largely by means of ice drifting from some antarctic region. The greater portion of the southern seas may have been at one time covered by ice floes, which would be coated with snow; this would afford a soft bed on which obsidianites would fall and cool, and the floes might then drift to and strand upon Australian shores; the ice would in time melt and deposit them there.

How long, in geological time, these superficial deposits have been accumulating we have no means at present of knowing; the planing down and shaping of the present surface of the underlying crystalline and metamorphic rocks has probably proceeded uninterruptedly throughout a vast stretch of time.

There is no sign that any great thickness of sedimentary strata ever covered those rocks, as is the case in the eastern portion of Australia. What are now on the surface are but the stumps of

former mountains and dykes traversing the latter; the most recent appears to be the remarkable band of norite which forms an east and west range, varying from one mile to half a mile wide, and of which Trig. Hill B 23, near Princess Royal township, forms a part (Fig. 5). This immense dyke extends in an uninterrupted line to Mount Norcott, about 12 miles to the eastward, and further beyond that, while to the westward it passes to the other side of Lake Cowan. No intrusive rocks occur in this norite, which would thus appear to be the most recent of all in this district.

Three analyses of this rock are given in Table II. The structure and analysis of mineral specimen [**5646**] from the point at the east end of the Causeway shows it to be a change towards a hypersthenite, on the west side of Lake Cowan it is a peridotite on the south margin of the dyke. Mineral specimen [**5696**] from Mt. Norcott may be taken as typical of the norite; a section of this has been examined in the Departmental Laboratory, and is thus described :—

"Coarsely granular, the most frequent mineral is a fresh multiple-twinned *plagioclase felspar*, almost wholly transparent, but a little cloudy in places, with numerous dusty inclusions mainly along cleavage lines. *Diallage* is the next most frequent, it occurs in large angular or rounded fragments, with well-marked schiller structure; colour pale green or smoky. Twinning occasionally gives rise to herringbone structure. *Hypersthene* occurs in large rounded grains with numerous dusty inclusions, and is intimately associated with diallage. It is faintly pleochroic, pink to pale green, with small marked changes at times. *Iron ores* are represented by a few small irregular grains and *hornblende* by a few small irregular fragments of green hornblende."

Mineral specimen [**5439**] from the road line west of Trig. Hill and [**5581**] from the bluff on the west side of Lake Cowan are very similar to this. In the former, portions of the diallage show a fringing of hypersthene, one being apparently in process of merging into the other. The examination of [**5646**] shows it to consist almost entirely of coarse granular hypersthene, and in the interstices are small pieces of felspar.

The next older in age probably are the granite-porphyries closely associated with the quartz veins, they appear to follow the same lines of fissure as the quartz reefs. Some of these granite-porphyries may be earlier and some subsequent to the reefs. In Mt. Benson No. 1 Extended, G.M. 52, it forms the eastern dyke, and is probably the dyke that is said to cut through the quartz reef; in hand specimen [**5985**] it appears to be a fine-grained whitish rock, with small black crystals scattered through it. The laboratory description states that it is somewhat coarsely granular and largely micro-pegmatitic :—

"*Felspar* and *quartz* are in large separate individuals, surrounded by areas of same closely intergrown giving a pegmatite structure, felspar mostly untwinned, but some grains show single and others multiple twinning. *Biotite*—Numerous aggregates of small scales."

Another example of granite-porphyry occurs at the Italia, G.M.L. 165, near Lake Kirk [**6004**]. This is very dark in colour,

Photo., M. B. Woolcoc .

Govt. Photo. Litho.

Trig Hill, Princess Royal, Norseman, view looking east.

almost resembling the amphibolite. The Laboratory description states it to be—

"Probably a granite-porphyry, the felspar of which forms a finely granular base, but the species is indeterminable. *Muscovite*, coarsely fibrous, very frequent. *Biotite*, strongly pleochroic, pale yellow to deep brown, common in scales and fibres. *Iron ores* consist of irregular grains. *Quartz*, frequently interstitial. *Sodalite* (?), occasional large colourless crystals, isomorphic. Numerous inclusions."

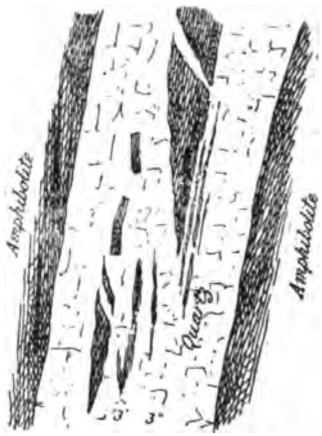
What is probably a granite porphyry accompanies the quartz reef in Norseman No. 1 North, G.M.L. 16, in the 100 feet level, south of the main shaft, sometimes on the hanging wall and sometimes on the foot wall; it is there looked upon as an indicator of gold in the reef, the sample obtained was too much decomposed for determination.

The auriferous massive quartz reefs are scattered over a wide extent of country, including most of the area in which the quartz porphyry dykes and banded quartzites and ironstones occur. Intersections with the dykes are favourable for values. Usually the best defined wall is on the hanging wall side of a reef, also clay partings, and slickensides mostly occur on that side, as may be seen at the Lady Mary and St. Patrick G.M.'s; but where there is laminated quartz, it is generally on the foot wall side, as at the Northern Star. In the Norseman and several other reefs, a good deal of calcite occurs. In the banded quartzite and ironstone area, the reefs are often more chalcedonic and lode like, partaking somewhat of the character of the surrounding rock, which is to be expected. With the exception of the Norseman line of reef, which is about two miles long, the reefs are mostly short and vary greatly in mode of occurrence, some have well-defined walls, as at the Cumberland (Fig. 6) and Northern Star, and portions of the Princess Royal, while others have scarcely any or no walls at all, and are greatly contorted as if following the foldings of a plastic condition of the amphibolite rock as at the Desirable and Valkyrie G.M.'s and part of the Viking workings of the Norseman G.M. This may be explained by the condition of great pressure which must have prevailed at times when the reefs were formed, causing probably but little difference between infiltration and intrusion of the superheated siliceous liquid. It is also conceivable that, given pressure and heat, hydrothermal and molten deposits of silica may be identical and make possible a connection with gradations, which would include orphyry, between these reefs and veins and a deeper seated granitic source. The accompanying sketch (Fig. 6) shows how portions of the country rock are at times entangled in the quartz orming the reef.

The main quartz and lode lines approximate to the magnetic eridian and the chutes of ore approximate with the magnetic p southerly; but notable exceptions occur at the Northern Star d Lady Mary G.Ms., where the chutes dip to the north. The osition of ores is, possibly, if not probably, due to a considerable

extent to magnetic action, so that the presence of magnetite should be highly conducive to the occurrence of gold, and this is what the writer has found to be approximately the case from Sawpit Gully to the south boundary of the map, though most magnetite occurs on the easternmost ridge, where, as yet, not much gold has been found. It is somewhat curious that the presence of magnetite in this district had not been previously observed.

FIG. 6.



HALL'S REEF AT 250' LEVEL CUMBERLAND G.M

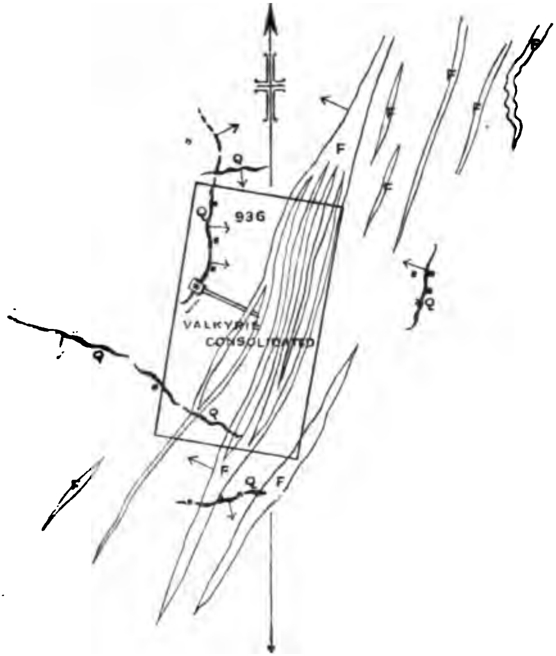
A very noticeable occurrence is the enrichment of the reefs when they pass through dykes: possibly, this enrichment is partly due to mechanical action, the interruption of the passage of ore material, but it is also, probably, partly due to the interruption of magnetic currents along the reef and dyke lines.

The special character about the reefs throughout the banded ironstone area is the way in which the gold is deposited at intersections with the ironstone bands. The iron has had such a precipitating effect that the surrounding kaolin has often been also heavily charged with the precious metal, forming a lode-like deposit, as at Ziegler's Find and Lucky Call G.Ms. Apparently, isolated patches of gold are characteristic of this line of country, and it would be in most cases too hazardous to attempt the excavation in bulk of a large body of these banded rocks on the strength of a few of these pockets of ore. The subject of reefs is discussed also in the economic geology section.

The injection of the molten material which formed the felsite and quartz-porphyry dykes in fissures in the amphibolite rock belongs to a date or dates anterior to the formation of the reefs, as the latter pass through them; these dykes show a remarkable parallelism and persistence over several miles' length of country, in

a direction about 24 degrees east of north and vary from 2 or 3 feet to 150 feet in width, and are sometimes only 50 feet apart. At the Valkyrie mine they appear to divide up into a series of parallel dykes, which reunite again at a quarter of a mile distance (Fig. 7).

FIG. 7.



PLAN OF THE VALKYRIE DYKES.

The numerous felsite dykes met with in the workings of the Princess Royal show a green siliceous rock with a waxy lustre, which decomposes readily on exposure to the atmosphere. The laboratory description of specimen [6111] is:—

"Micro-crystalline, with occasional porphyritic quartz grains. Quartz: A few coarse grains, with dusty inclusions; it is also finely granular in base. Felspar: Finely granular base, largely felspar. Pyrites: Occasional coarse, irregular grains. Iron ore: Some small sporadic grains."

The presence of these dykes is distinctly favourable to the deposition of gold where quartz reefs intersect them. An analysis of this felsite is given in Table II.

Quartz porphyry forms the greater number of the dykes in this district, the felsites being apparently confined to the neighbourhood of the Princess Royal. Both are locally termed quartzites, but this is incorrect, as they are not altered sedimentary rocks. Although these dykes must be far more recent than the formation of the banded quartzites and ironstones along the eastern margin

of the area mapped, it is noticeable that they do not intersect them, and although their trend is oblique to that of the sandstones, etc., they become deflected to a more north and south direction, where they approach them, as if the latter were too pliable or tough to be cracked or fissured. The banded quartz porphyry occurs also mostly along this eastern margin of the amphibolite.

The quartz porphyries vary very much in colour, from white to black, but always exhibit glassy beads of quartz scattered throughout their mass. They are occasionally pyriteous and slightly auriferous. The laboratory description of specimen [**5969**], a somewhat slaty sample, being :—

"Typical quartz porphyry, having porphyritic grains of quartz and iron ore imbedded in a micro-crystalline base of quartz and felspar.

Mineral specimen [**5946**]. *Microstructure*: Micro-crystalline, a very little quartz is porphyritic, strongly banded, with occasional typical spherulites. *Felspar*: Very finely granular forming a large part of the section. *Quartz*: Slightly coarser grains, largely developed in bands and irregular lenses. *Hornblende*: Still more coarse, very numerous scattered fragments arranged in bands and clustered round spherulites. *Iron ore*: Sporadic.

Mineral specimen [**5612**]. Foliated, micro-crystalline, porphyritic with flow structure, round quartz grains. *Quartz*, in large porphyritic grains, with dusty inclusions, and in masses of very fine grains. *Felspar*, very finely granular, forms great portion of base.

Felspar porphyry occurs in a dyke near Lake Dundas about five chains east of G.M.L. 328, among the metamorphosed sandstones. The Laboratory description of mineral specimen [**5940**] being :—

"Structure—fine-grained, slightly porphyritic; weathered *felspar*, in porphyritic crystals and fine grains much clouded, no twinning. *Biotite*, deep yellowish greenish to pale yellow in scattered irregular grains. *Quartz* in small interstitial grains. *Iron ores* in fine grains.

At the eastern base of a hill about 2½ miles east of the Norseman Government Tank near Lake Dundas there is a large dyke of granite [**6034**] flanked on its western side by porphyry [**6029**], [**6032**], [**6033**] and then again by quartz porphyry [**6031**] which is crushed on its western side into a mica schist [**6030**]; the adjacent amphibolite is also crushed into a foliated and slaty condition; there is a small quartz vein in the schist; some prospecting holes and claim posts indicate that probably some traces of gold were found here. The granite appears slightly crushed, but the amphibolite, adjacent on its eastern side, does not show much sign of alteration. A quarter of a mile further east, on the other side of an arm of the lake, a large pegmatite vein outcrops.

The analysis of a sample of this [**6035**] shows it to be composed of almost pure quartz :—

S_1O_2	98·01
CaO	·44
K_2O	·13
Na_2O	·48
Al_2O_3	·82
	99·88

The quartz appears to be largely pseudomorphous after a soda-lime felspar, and shows zonary structure of felspar, *see* also [6036].

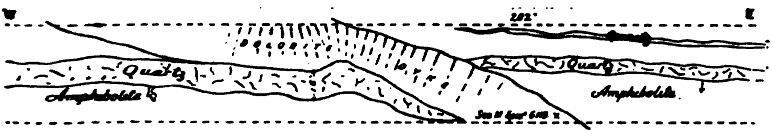
The cross section, comprising Plate V., shows this dyke. The laboratory description of a slice of the mineral specimen [6029] being as follows:—

"Structure—Coarsely granular quartz, felspar and biotite, with small crystals of zircon embedded in areas of fine grained quartz, felspar, and biotite."

An analysis of this specimen is given in Table II. The crushed samples of this rock show fractured crystals of quartz and felspar in a granular mass.

About the same age as the felspar porphyries probably were the various scattered intrusive veins and dykes of dolerite; a good sample was met with in the Cumberland G.M. at No. 1 level of the main underlay shaft, at 242 feet easterly, a sketch of which is shown below (Fig. 8). The dyke as an incipient form of columnar

FIG. 8.



SKETCH PLAN

DOLERITE DYKE CROSSING REEF 145' LEVEL MAIN UNDERLAY SHAFT CUMBERLAND G M.

Scale of feet

jointing so often assumed by basaltic rocks, which are merely a finer grained variety of this rock. Although the dyke passes uninterruptedly through the line of the quartz, the impression left in the mind after a careful inspection is that it is probably the older of the two, for the quartz on one side of it is in two smaller veins, as if the siliceous solution had found its way through the dolerite at some place and resumed its line of deposition of silica in divided portions. An analysis of this specimen [6119] is given in Table II. The laboratory examination of this rock is:—

"Structure—Micro-porphyritic. *Felspar*, in small lathe-like crystals, forming about one-half of the base. *Augite*, in small grains forming a large part of the base. *Ilmenite*, often altered to leucoxene, frequent in fine grains in base. *Olivine*, in large colourless porphyritic grains, very fresh, with fairly numerous fissures and inclusions. Sometimes twinned. *Hornblende*, a few green pleochroic and porphyritic grains.

The next class of rock to notice is diorite; its structure shows well developed crystals, showing that it has solidified under pressure, usually in dykes or horizontal expansions termed laccolites. In this district, however, it behaves mostly as large lateral sheets or flows which appear to be and were probably intruded while the amphibolite was in a semiplastic state, almost or quite contemporaneous with the amphibolite. The amphibolite must be the result of sub-

marine eruption, as it is interbedded with the metamorphic sandstones and conglomerates and has a bedded and even almost slaty character in places [5471, 5582, 5901].

A diorite dyke [5995] occurs between the two quartz porphyry dykes at the Star of Erin G.M.L. 946, where it is noticably harder than the more decomposed amphibolite around. The Laboratory description is as follows:—

Hornblende, green pleochroic hornblende forms the greater portion of the section, in coarse crystals without regular arrangement *Felspar*, plagioclase in long slender multiply-twinned crystals somewhat frequent, as are also enclosures of hornblende. *Iron ore*, numerous small sporadic grains.

At the main shaft of the Princess Royal South Extended G.M.L. 647, two classes of rock are very noticeable, these junction near the bottom of the shaft; the finer grained one is diorite [5471]; it shows a flow character, having distinctly defined and rounded margin, it is considerably harder than the coarser rock, which is amphibolite. The Laboratory description of this diorite is:—

"Structure, finely crystalline (aphanitic). *Hornblende.*—Bright green hornblende forms the larger part of the rock in small interlacing crystals, with ragged edges penetrating the felspar and frequently fibrous in structure. *Felspar*, in small irregular grains between hornblende, and also in long, narrow, clear crystals with very low extinction angle, probably, therefore, albite, contains numerous small inclusions of hornblende. *Iron ores*, very many small irregular grains."

The intrusive veins [5580] that can be seen in the coarsely crystalline amphibolite at the foot of the hill on the south side of the clay pan about one mile north-west from Princess Royal are probably diorite.

A mica-diorite dyke occurs along the centre of the banded quartzite and ironstone south of the Bon Accord, G.M.L. 734, [5942]. The Laboratory description is:—

"Structure, finely granular. *Felspar* in finely granular masses. *Biotite*, small flakes of brown biotite singly or in aggregates, very numerous, strongly pleochroic, straight extinction in many fragments. *Quartz* in numerous small interstitial grains. *Iron Ore* mainly *Ilmenite* altered into leucoxene."

A few feet west of this sample the rock becomes a *Biotite schist* [5961]. The analysis is given in Table II. The laboratory description is:—

"Structure, finely granular. *Biotite* most common mineral, in small brown strongly pleochroic grains. *Felspar*, fine grains between mica. *Quartz*, a few interstitial grains. *Iron ores*, scattered grains of various sizes not very common."

Hand specimens of this and the previous and subsequently described varieties are, however, hardly distinguishable from each other. The western side of this dyke becomes a hornblende mica-diorite [5962, 5963], which weathers into a peculiar honeycombed surface. An analysis is given in Table II. The Laboratory description is as follows:—

"Structure, coarsely granular. *Hornblende*, strongly pleochroic, deep green to light yellow, in large crystalline fragments. *Biotite*, frequent in

strongly pleochroic flakes, dark brown to pale yellow. *Quartz, Felspar,* and *Calcite*, numerous interstitial grains. *Ilmenite*, numerous irregular grains. The section shows a vein with quartz hornblende and zeolite?

Besides these diorites there are masses of rock which differ from the true diorites in that their hornblende is undoubtedly secondary, and probably derived from the alteration of a pyroxene, and are therefore classed as *Epidiorites*, but it is included in the same colour as the amphibolite in the map. Epidorite occurs at the Desirable G.M.L. 848 [5441]. The Laboratory description of which is:—

Structure—"Coarsely crystalline, strongly metamorphosed. *Hornblende*, large crystals, strongly pleochroic, bluish green to yellow, some singly twinned, some fibrous in structure, and almost all with feathery terminations. Also in felted masses of fine crystals, and in small crystals embedded in quartz and felspar, undoubtedly of secondary origin. *Felspar*, completely altered to a cloudy aggregate of secondary albite, epidote, etc. Numerous small enclosures of hornblende. *Quartz*, in numerous masses with ill-defined irregular boundaries of spicular hornblende, altered felspar, etc., and enclosing numerous spicules of the former, also irregular fragments of the latter, evidently secondary. *Ilmenite*, large skeletal crystals as well as small grains, which probably also include some magnetite."

Another mass of epidiorite forms the west boundary of Lake Kirk at the Sunbeam G.M.L 157 [5999]. The Laboratory description of which is:—

"Structure, coarsely crystalline. *Hornblende*, very pale, fibrous, and sometimes sheaf-like, with feathery ends; also in numerous embedded spicules, all undoubtedly secondary. *Felspar*, finely to coarsely granular, occasionally multiply-twinned; numerous inclusions of hornblende. *Quartz*, a little interstitial. *Iron ores* in large and small angular grains."

These epidiorites and their modifications are so greatly intermixed with the surrounding amphibolites that form the bulk of the country rock, that it has not been found possible to map their boundaries, they are almost certainly portions of the one rock mass.

A porphyritic diorite occurs at Buldania, a reference to which is given in a brief notice of that group of leases at the end of this section of the report.

We come now to the material of which the greater portion of the country rock of the district is composed, viz., AMPHIBOLITE. It assumes a great variety of forms; the normal type varies from coarsely granular to aphanitic, it is slightly amygdaloidal at the [illegible]nt north of the west end of the Causeway. It has planes of [illegible]lding that may be plainly seen in the cliffs of the islands and [illegible]ng the west side of Lake Cowan, underlying about 65 degrees to [illegible] west. In general character the rock is massive and occasionally [illegible]ey, as at the islands and cliffs previously mentioned. A schistose [illegible]racter is sometimes developed, where quartz veins and quartz [illegible]phyry dykes occur in their immediate vicinity; this foliation is [illegible]ys in the plane of the reef or dyke. A sample [5980] from the

300-feet level at the Cumberland main underlay shaft, a grey coloured rock, is thus described in the Laboratory examination :—

"*Hornblende*, light green in large and small crystals. *Biotite*, numerous brown scales irregularly distributed and apparently replacing hornblende. *Felspar*, finely granular, interstitial. *Iron ore*, very numerous, large and small grains."

Another from about 200-feet level of the Lady Mary main underlay shaft [**5462**] is :—

"Coarsely crystalline. *Hornblende* (Uralite) forms the bulk of the rock, in large sheaf-like bundles of pale green and yellow fibres. Undoubtedly secondary. *Iron ores* (Ilmenite and magnetite), in numerous large and small grains of irregular outline."

These descriptions are typical of the general character throughout each mine.

Another specimen [**5472**] from the Princess Royal South Extended, G.M.L. 647, has a coarsely crystalline structure :—

"*Hornblende*, forms the greater part of the rock, in large crystals mostly very pale green, occasionally deeper green or brown. Some crystals, fibrous, and many with feathery terminations, also in areas of small felted spicules. Small inclusions of iron ores very numerous, hornblende almost wholly secondary. *Felspar* represented by relatively few irregular ores very much clouded through alteration. *Ilmenite*, many large fragments altered almost completely to grey transparent leucoxene. Much fine dusty black matter, which may be ilmenite or magnetite."

As a type of the aphanitic amphibolite, we may take that which forms a large part of the top of the high hill about two miles north of Princess Royal [**5448**]. The Laboratory description is as follows :—

"Structure finely granular. *Hornblende* forms main bulk of rock in a mass of small interlacing crystals, pleochroic, pale green to yellow, probably secondary. *Ilmenite*, in large and small irregular grains, mainly altered to leucoxene. Secondary *Quartz*, felspar and probably *calcite* fills small interstices between hornblende."

An analysis is given in Table II. of the amygdaloidal amphibolite [**5650**] from north of the point at the west end of the causeway. The Laboratory description is :—

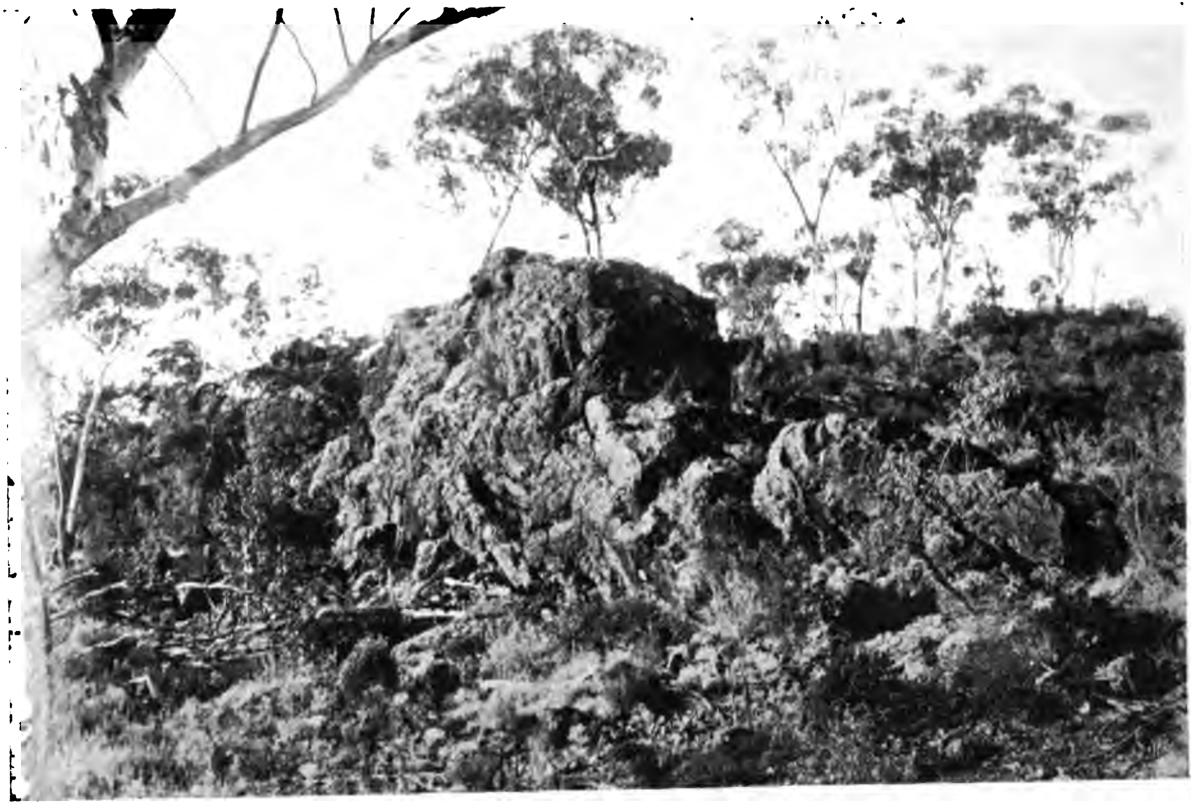
"Structure, finely crystalline. *Hornblende* forms almost the whole of rock in radially fibrous spherules and interstitial masses, evidently secondary. *Iron ores*, in scattered, irregular grains. *Quartz*, a few small interstitial grains and veinlets, calcite ditto, also in amygdaloids (?)."

Sample [**5593**], from the cliff opposite the large island in Lake Cowan, is described thus :—

"Structure, coarsely granular. *Hornblende* forms major portion of rock in large and small crystals, pleochroic, bright green to yellow. *Felspar* finely granular, interstitional, full of hornblende enclosures. *Iron ores*, very numerous, small grains. *Quartz*, a little interstitial."

Along the western side of Lake Cowan the amphibolite is harder than on the eastern side, more resembling the Buldania type; this is probably due to metamorphic action. This action has also induced a modification of the amphibolite, towards an actinolite rock, in places, chiefly between the quartzites. The Laboratory

FIG. 9.



Govt. Photo. Litho.

description of sample [5655] from G.M.L. 104, north of the Lady Jean, which shows this change, is :—

"*Hornblende*, large fibrous sheaf, like crystals, pale green and yellow, evidently secondary, altered in places to *Biotite* in small brown scales. *Iron ores*, large and small irregular grains. No felspars or quartz visible."

Another actinolitic sample [5936], from Bon Accord, G.M.L. 734, is stated to contain :—

"*Hornblende* pale green and yellow pleochroic in interlacing fibrous crystals. *Biotite*, brown pleochroic scales frequent. *Muscovite* (?), present in colourless or pale green flakes. *Iron ore*, in scattered grains and granular aggregates common.

Another sample [6021], from the Lady Millar, contains :—

"*Hornblende*, frequent in small fibrous crystals, pale green. *Biotite*, very common in brown pleochroic flakes, probably derived from the alteration of the hornblende. *Iron ore*, few small scattered grains."

Interbedded in these amphibolites there are a number of north and south beds of sandstone and conglomerates, the centres of which have been metamorphosed, chiefly by silicification and mineralisation, into a series of bands of quartzite and ironstone, sometimes jaspery; these occupy a strip of country about a mile in width (Fig. 9). A distinction has been made in the mapping between the slightly metamorphosed portions and the quartzites, but they were originally identical. The main core, so to speak, of quartzite is often composed of several subsidiary jaspery or ferruginous bands. They form a most diversified series of rocks, mostly ferruginous, occupying a strip of country about a mile in width, skirting the west side of Lake Dundas, and near the west side of Lake Kirk. The series of parallel repetitions of these quartzites may be explained by there being a folding of the strata by great lateral pressure, this is shown by dotted lines on the cross section plate. If this is the correct interpretation, then the metamorphic sedimentary beds may be not more than about 800 feet in thickness.

Near the norite dyke, the quartzites become also slightly crumpled by pressure applied in their longitudinal direction.

A peculiarity occurs in the quartzite of the ridge east of the Bon Accord, G.M.L. 734; the planes of bedding are here almost perpendicular, and it has in addition joint planes dipping 25 degrees north.

Throughout this series of beds, it has been already mentioned, quartz reefs and veins are frequent; these are of later origin than the silicification of the banded quartzites and are generally moderately auriferous and rich in places. There can be here no manner of doubt as to the sedimentary origin of these beds and their contemporaneity with the amphibolite; sometimes the banded quartzite and ironstone occurs in thin bands in the amphibolite, in which case the latter is usually actinolitic. [5936, 6013, 6021].

The metamorphic sandstones were possibly mistaken for tuffs and phyllites by Mr. Göczel, and the conglomerates are probably those to which Dr. Chewings alludes in his paper previously quoted.

Figure 10 shows a sample of this conglomerate from the Belmont, G.M.L. 789 [5938]; similar samples can be obtained from the west side of the Star, G.M.L. 835, about 30 chains north-easterly from the Belmont and also from numerous other places within the limits of this formation. The Laboratory description of specimen [6129], from Bon Accord, is—

"crushed conglomerate. Large fractured masses of *chalcedony* and *quartz* full of inclusions of limonite and other iron ores. *Ilmenite* partly altered to leucoxene, base largely composed of flakes of *biotite* with granular quartz and limonite."

Specimen [6017] is described as a—

"crushed sandstone. Quartz in large and small angular and irregular grains as well as in areas of crushed fragments, set in a fine grained base of quartz and felspathic material. *Limonite* frequently in globular masses frequently surrounding small black cores of magnetite (?), a grey and almost opaque mineral like *Leucoxene*. *Muscovite* in scaly aggregate.

Specimen [6130]—

"Quartzite. *Quartz*, very finely granular quartz (chalcedony) in large, irregular fragments due possibly to fracturing, the fractures or interspaces filled with more coarsely granular quartz. *Iron ore* pyrites in crystalline grains of all sizes frequent. A black iron ore, ditto. *Limonite* common.

This proof of the origin of the banded quartzites and the contemporaneity of sedimentary and volcanic products agrees with what the author has recorded in his field notes on the Kalgoorlie Goldfield, where the strike and underlay of both the banded quartz and slates coincide with that of the cleavage of the surrounding rock, usually 325 degrees, and an underlay of 75 degrees to the west, and that the argillaceous slates blended with the schists of the crystalline rocks. The cross section of the Boulder Belt, published in 1903, indicates the principle. The results of this Norseman survey are of great assistance in elucidating clearly many matters which were obscure at Kalgoorlie.

In the Norseman district, no argillaceous slates appear, but the quartzites are 1,500 feet in width in several places. The condition of these metamorphic sandstones and conglomerates evidently much resemble the metamorphic conglomerates of the Vermont formation at the Hoosac Mountain in Massachusetts, which have been found to pass gradually through stages of metamorphic conglomerates and quartzites, and gneiss-conglomerates into gneiss and granitoid gneiss (*see* Monograph, vol. 23, of the United States Geological Survey, p. 48), and from their similarity would seem to afford an indication of the origin of the extensive gneiss rocks of this State.

A two days' holiday visit was made to Dundas, 14 miles south of Norseman, where there is a considerable extent of granite, but it is probably also a later intrusion in the basic rocks. The Laboratory description of specimen [5602], from Noganyer Soak, is as follows:—

"Structure, coarsely granular. Quartz in large grains, with a few dusty inclusions and many extremely fine long crystals of Rutile (?). *Orthoclase*: Mostly untwinned and somewhat cloudy. *Microline*: Coarse grains

Photo., W. D. Campbell. Govt. Photo. Litho.

Metamorphic Conglomerate, G.M.L. 789, Belmont.

numerous with cross hatched structure under crossed nicols. *Biotite:* Numerous large irregular fragments, very strongly pleochroic, green or brown to black. Iron ore a little associated with the biotite."

The banded quartzites and ironstones skirt the edge of the lake the whole distance to Dundas. I was informed that there are also some southward of that place as far as a bluff at the lake edge about four or five miles south.

Quartz reefs and lodes appear at intervals throughout this distance, and groups of leases have been taken up along them, but nearly all have been abandoned for many years. Work was proceeding in a desultory sort of way at Mawson's Reward by dollying the best available stone. The reef has well-defined walls and a fair body of stone, and if a battery was available, it should do well. Since my visit operations at the Break o' Day have been renewed. The mine appears a good one. Whenever battery facilities are afforded this district, or a mineral tramway is made through it from the State battery at Norseman, it should be a profitable mining district.

Although Buldania, situated about 17 miles north-easterly from Princess Royal, was not within my instructions, a day's inspection of that part was made. The country rock appears to be amphibolite and diorite; some of the latter is porphyritic with quartzite and ferruginous formations, having quartz veins forming sulphide lodes and in parts intersected by quartz porphyry dykes. The rock is harder than at Norseman, and there is not more than about three feet of decomposed ground.

Gold was discovered here in June, 1896, and a strip of land about 1½ miles long was taken up in leases between that time and 1900—about 15 altogether—but they are all now extinct. A great many shafts were sunk to varying depths down to 100 feet. A few small crushings yielded very high returns, but the expenses proved too much for the limited capital of the leaseholders, mostly prospectors. Five distinct lodes are said to have been opened up; they are parallel and strike about 280 degrees. Mr. Catlin gives detailed descriptions of nine of the principal mines. One rock specimen from the Mia Mia G.M.L. 676 is peculiar, being a porphyritic diorite. The Laboratory description is [5927] is:—

"*Felspar* much clouded, in large crystals, no twinning, also a clear finely granular felspar between the larger crystals. *Hornblende,* well-formed crystals of all sizes numerous, pleochroism strong, pale yellow to deep green or brown. *Iron ores,* a few irregular grains."

Economic Geology.

The recent superficial deposits in the Norseman district have yielded only a limited amount of alluvial gold, the total reported from 1899 to 1904 inclusive being 1,662·37ozs. The alluvial workings are of small extent, and are mostly confined to some of the gullies trending eastward through the banded quartzites and ironstones. The gold is found at the base of gravel ranging from a few inches to 8 feet in depth. Narracoorte and Salvado's gullies

have probably yielded the most gold; in both cases there was a considerable amount of laterite and ironstone gravel in close proximity to the gold patches; these had probably a precipitating effect on any gold in solution after its being dissolved out from the decomposing rocks and veins. The bottom is mostly banded ironstone and metamorphosed sandstone. Where the bottom is composed of concretionary material such as laterite and travertine (cement) it requires proving, in case false bottoms occur. The author was able to see only a few samples of the gold from here; it was of a shotty character, but it ranges from fine to nuggets of 3 to 4 dwts.

In February, 1901, the deep lead at Princess Royal was discovered by Messrs. Steadman, Sheppard and Cooper, these alluvial workings were mostly in the main street, and it was worked out in about six months. The depth was 88 feet in kaolin. Above the "wash" there is a white pug showing the usual slickensides and crush faces [**5475**], and above this in places there are ironstone gravel patches, technically termed "headings." The wash itself is mullocky, with concretions of a magnesian nature, with quartz particles, etc. [**5476**]. The gold was chiefly in the bottom of six inches of this and is probably partly secondary. This wash is said to have been 30 to 40 feet wide, and to have increased in thickness on the west side to about six feet, forming a kind of bank; most of the auriferous portion was on the side of this bank. Below this there is a gritty brown material, evidently decomposed hornblendic rock [**5477, 5478**]. The cap of a quartz vein three or four inches thick showed in some of the workings and oxidised amphibolite rock.

At the Lady Mary gully a deep lead was found at a depth of 90 feet in kaolin, adjacent to the existing watercourse, where it leaves the hills. There is a surface fall here of about 145 feet to the lake level. At 40 feet depth ironstone patches were met with, and at the bottom, which comprised kaolin and oxidised amphibolite, large boulders of quartz were found cemented in the pug and also black sand. The best gold was obtained where the large quartz occurred, and yielded about 12dwts. per ton. The last shaft where gold was reported was about 250 yards east of the first one. On the dumps of these shafts are to be seen large lumps of a secondary form of silica, pisolitic, ranging from earthy concretions to solid quartz [**6127, 6128**]. The sharp edges and absence of water-worn edges in some of the gold found here leads one to believe that some of this gold must be of a secondary origin.

The great area of ground over which the quartz reefs extend has enabled a large number of leases to be worked by parties of miners; they yield moderate returns with occasional rich patches. The main lines of reef are approximately north and south, with an underlay to the east of about 45 degrees, those bearing east and west underlay south about 60 to 70 degrees; this is in the amphibolite area. In the Cumberland and adjacent mines the reefs are often accompanied by "formation or gangue," caused probably partly by chemical action and partly by crushing or attrition of the

Photo., W. D. CAMPBELL.

Govt. Photo. Litho.

Limekiln, M.L. 1, Lake Cowan, looking south.

sides of the [illegible] in which the [illegible] is sometimes [illegible]. The [illegible] porphyry dykes is [illegible] as at the Princess R[illegible] and [illegible] the arresting of the [illegible] currents along [illegible] great length: the [illegible] Princess Royal G.M. [illegible] feet, Viking [illegible] feet; and the [illegible]

The larger reefs have a [illegible] or [illegible] oxidation at the surface [illegible] stated to [illegible] near the surface [illegible] of the Norseman Hill [illegible] sulphide ore being [illegible] ore of tungsten [5938] [illegible] appears as a [illegible] gold in panning [illegible] ton if in sufficient quantities [illegible] the district, and if [illegible] from the battery sands. [illegible]

The quartz reefs which traverse the banded [illegible] ironstones sometimes [illegible] Lord H[illegible]: they vary [illegible] the nature of the rocks in which [illegible] dark and ferruginous and [illegible] [5925] [illegible] banded ironstones: [illegible] chalcedonic character [5933]; this is a [illegible] infiltration of the iron and silica from [illegible] to act as a precipitant to any gold in solution, which [illegible] explains the erratic way that gold patches [illegible] which have yielded in places some extraordinary [illegible] and the gold particles are in places clustered [illegible] in preference to the quartz in the banded [illegible] [6573].

A good many patches of a dolomitic limestone occur to the north and east of Norseman; on one of these is the [illegible] No. 1, where there has been erected a kiln (Fig. 11), which supplies an impure lime, which suffices for local requirements. The great cost of freight of such material, when brought from Fremantle, is quite prohibitive; the following is an example from the Princess Royal Mine:—

	£	s.	d.
[illegible] casks at 13s. 6d. f.o.r., Fremantle	[illegible]	[illegible]	[illegible]
Railage to Coolgardie	[illegible]	[illegible]	2
Cartage from Coolgardie to Norseman at £9 per ton	12	[illegible]	4
Forwarding charges	0	[illegible]	[illegible]
	22	[illegible]	[illegible]

Photo., W. D. CAMPBELL. Govt. Photo. Litho.

[illegible] Lake Cowan, looking south.

sides of the fissure in which the reef has formed, subsequently, as it is sometimes brecciated. The intersections with felsite and quartz porphyry dykes is favourable to the deposition of gold in the reefs, as at the Princess Royal and Valkyrie G.Ms., probably due both to the arresting of the ore solutions and to interruptions of magnetic currents along both reefs and dykes. The chutes are sometimes of great length: the combined centre and southern chutes of the Princess Royal G.M. are 1,000 feet; the Mildura Norseman, 900 feet; Viking, 600 feet; and the Lady Mary, 1,200 feet.

The larger reefs have a considerable amount of either galena or pyromorphite, which contains silver. Galena, owing to its rapid oxidation at the surface, is seldom seen in outcrops, though it is stated to occur very near the surface at the Ajax at the end slope of the Norseman Hill, where there is very little decomposed rock, sulphide ore being obtained here at a shallow depth. Scheelite, an ore of tungsten [**5960**], occurs in the quartz at the Record, and appears as a dull brown sand in dollying or milling; it clings to the gold in panning off, as it is heavy. It is worth from £20 to £60 a ton if in sufficient quantities. It has been reported previously from the district, and if in sufficient quantity might be worth extracting from the battery sands. Bismuth is occasionally met with.

The quartz reefs which traverse the banded quartzites and ironstones sometimes coincide with their bedding planes, as at the Lord Hopetoun; they vary greatly in their character according to the nature of the rocks in which they occur, they frequently become dark and ferruginous and lode-like [**6023**] when they are in the banded ironstones; when in the quartzites they have frequently a chalcedonic character [**5933**]; this is a result of the segregation and infiltration of the iron and silica from those rocks. Iron appears to act as a precipitant to any gold in solution, which probably explains the erratic way that gold patches occur near ironstone which have yielded in places some extraordinary rich results, and the gold particles are in places clustered along the ironstone seams in preference to the quartz in the banded quartzite and ironstone lodes [**6573**].

A good many patches of a dolomitic limestone occur to the north and east of Norseman; on one of these is the mineral lease No. 1, where there has been erected a kiln (Fig. 11), which supplies an impure lime, which suffices for local requirements. The great cost of freight of such material, when brought from Fremantle, is quite prohibitive; the following is an example from the Princess Royal Mine:—

	£	s.	d.
8 casks at 13s. 6d. f.o.r., Fremantle	5	8	0
Railage to Coolgardie	4	11	2
Cartage from Coolgardie to Norseman at £9 per ton	12	7	6
Forwarding charges	0	8	0
	22	14	8

Description of the Mines.

The mines and reefs described in the following pages are taken in two groups, the amphibolite or basic and the banded formations or acidic, both begin with the north-westernmost.

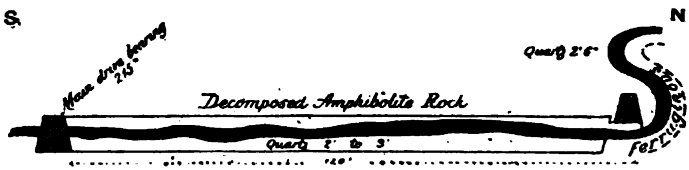
The first is the group of reefs comprising the *Desirable Proprietary* and the *Three Colonies* G.Ms. situated about one mile westerly from the Princess Royal township.

The Desirable Reefs.

The two main Desirable reefs have a curved outcrop, trending north-easterly, and about 1,000 feet in length; they sweep round towards the north-west and overlap at the centre; the general dip is to the eastward. The southern end of the outcrop enters what was originally the Little Pearl Lease, at a point about 140 feet south from the northern angle of the lease; the northern limit of the outcrop is in the old Missfire, G.M.L. 89.

The southern three-fourths of these lines of reef were held by the Desirable Proprietary G.M., which had seven leases with a total area of 76 acres. Both reefs had an inclined main shaft, which were about 100 feet apart at the surface but with divergent directions easterly, these are in the DESIRABLE No. 1, G.M.L. 84. The northernmost shaft is 230 feet on the underlay, equivalent to a vertical depth of 80 feet, the inclination being 30 degrees for the first 100 feet and then decreases to about 15 degrees below this. At the 90-foot level there is a drive 210 feet north with stoping to the surface, and 70 feet south; the width of reef ranges from 6 inches to 3 feet with an average of about 18 inches. The reef pinches out at both ends. The workings were not accessible below 150 feet, but Mr. Catlin's account states that at 160 feet a drive is 90 feet to the north, 130 feet to the south, whilst at 200 feet a drive goes 80 feet to the south and at this depth the reef gives out. The southern, or No. 2 shaft, is on a reef that overlaps the above described workings and the shaft has a more southerly direction, caused by the splaying of the two reefs. This shaft has an inclination of 35 degrees for the first 100 feet, and then 15 degrees below this, following the reef throughout. At the 70-foot level drives have

FIG. 12.



CROSS SECTION AT 125' LEVEL DESIRABLE G.M.

been put in 50 feet north and 230 feet south. At the 100-foot level a drive has been carried 210 feet south. The average width of the reef is about 2 feet At the 125-foot level, which is equivalent to the 160-foot level of the other shaft (No. 1) drives have been put in

100 feet north and 400 feet south respectively. At about 300 feet from the shaft at this level, the reef becomes horizontal and a winze goes north for 120 feet along this flat reef, which then takes a sudden sigmoidal turn vertically. The diagram which forms Fig. 12 indicates this sudden change in underlie.

The main drive here has turned due west, and further on the reef gradually rolls over till it has a northerly underlay. These reefs have yielded up to 2ozs. per ton in places, and at 400 feet in this 125-foot level the lessee stated that its value is about 15dwts. per ton.

In the shaft (No. 2) it was found that the water stood at about 160 feet, so that I have to refer to Mr. Catlin's description again for information. At the 180-foot level there are north and south drives of 170 feet and 100 feet respectively; this depth is about the same as that attained by the north shaft. A vertical shaft connects the bottom of the shaft with the surface. Nearly the whole of the workings are in the oxidised zone of epidiorite rock. Alternate bands of oxidised rock and kaolinized rock occur parallel with the reefs throughout the mine. The quartz has a good appearance; it is in places vuggy, but all the interstices are filled with Halloysite, or Mineral Fat, a hydrous silicate of alumina in a plastic state [**5618**]. An analysis of this is to be found in Table II. The presence of this mineral is detrimental to the ready extraction of the gold during amalgamation.

The northern end of this line of reefs was in G.M.L. 89, the Missfire, held by the Three Colonies Gold Mining Company, which put down both a vertical and an underlay shaft on it; according to Inspector Angove's report, the former, which cut the reefs at 25 feet and 52 feet, attained a total depth of 55 feet, the reefs being four feet and three feet thick respectively, the latter reef being made up of quartz and ironstone. He also states that a second shaft, 56 feet in depth, passed through two good quartz reefs four feet and three feet in width, at depths of 25 and 52 feet respectively, and that a drive 80 feet was put in on the reef at 25 feet. A third vertical shaft of 56 feet in depth evidently passed through nothing but country rock, as there is no record of any reef being struck in that interval. An underlay shaft had also been carried down to a depth of 38 feet on a quartz reef, which varied in thickness from 18 inches to four feet. The crushings from this reef were merged into those from G.M.L. 88.

The other leases held by the Desirable Proprietary Company have not had much work done in them, excepting Desirable South, G.M.L. 168, where two shafts have been sunk on parallel reefs; but these reefs, however, are not the same as the Desirable main reefs, unless separated by a fault.

In Desirable No. 2, G.M.L. 85 two shafts have been carried down to a vertical depth of 120 feet on a reef about 18 inches thick; they were all inaccessible at the time of my visit. The Company is stated to have spent £30,215 on the mine. The two leases previously mentioned were forfeited in 1901, and subsequently became

Q.C's. 87 to 90, held by Mr. Hopper for about three months during the same year; subsequently, the ground became in part LITTLE PEARL, G.M.L. 842, of six acres, which was surrendered in February of 1902; it became also, towards the close of 1901, in part DESIRABLE, G.M.L. 848, of six acres. Upon this lease another vertical shaft was sunk to 50 feet, near the east boundary, cutting a quartz reef of nine inches on the top of a roll of the hard, undecomposed, coarsely, crystalline epidiorite. This lease and G.M.L. 870 were purchased by the Princess Royal North Gold Mining Company in 1904, and is still in force.

A portion of 842 became the DESIRABLE EXTENDED, G.M.L. 870, in 1902, and comprised three acres, and is still in force.

The ground on the east side of these was taken up as the SUBSIDY, G.M.L. 891 of 18 acres, and having been forfeited in 1904, subsequently became the DESIRABLE BLOCK, G.M.L. 915, which is still in force.

The following table shows the yield of the Desirable Reefs, in so far as such can be gathered from the official statistics:—

Table Showing the Yield of the Desirable Reefs.

Year.	Name and No. of lease.	Ozs. dollied.	Tons crushed.	Tons cyanided.	Ozs. therefrom.	Ozs. from crushings.	Remarks.
Previous to 1897	Desirable 84, 85, 152, 168, 196, 228, 229	...	795·00	...	...	1,306·00	
1897 ...	Do.	...	2,921·00	...	...	2,154·57	
1898 ..	Do.	...	857·00	...	...	163·56	
1899 ...	Do.	...	32·00	...	...	294·13	
					Extras	6·96	
1900 ...	Do.	...		...	...		
1901 ...	Q.C. 87-90	...	116·00	...	...	91·57	State Battery.
1901 ...	Little Pearl 842 ...	..	11·00	...	...	5·60	
1901 ...	Primrose 845	...	4·00	...	...	2·45	
1902 ...	Do.	6·00	22·00	...	...	6·85	
				8·00	1·03	...	State Battery.
1903 ...	Rescue 875	...	13·00	...	...	5·28	
1902 ...	Desirable 848	...	50·00	...	...	23·75	
1903 ...	Do.	...	87·00	...	...	48·49	
1904 ...	Do.	...	277·00	...	...	62·38	=52·11 F.
1903 ...	Q.C. 148	...	12·50	...	...	3·57	
		6·00	5,197·50	8·00	1·03	4,175·16 1·03 6·00	
						4,182·19 or ·804 ozs. per ton.	

The Three Colonies Reef.

The THREE COLONIES REEF has a somewhat semi-circular outcrop of about 500 feet in length, and underlaying irregularly to the north; it outcrops on G.M.L. 88, THREE COLONIES, and is situated about 300 feet north from its southern boundary. It has been exploited by four shafts the positions of which are shown upon the Geological Map. An underlay shaft intersected the main reef at about 30 feet from the surface which depth marks the water level in the mine, from this point the reef was followed down to a depth of

85 feet to the north-east. The reef attained, it is said, the thickness of about three feet and carried a little gold. A main vertical shaft, situated a little over a chain north from the last and about 100 feet from the nearest point on the outcrop, failed to reach the reef as the Wellington force pump used is stated to have been unable to cope with the water. At 70 feet there is a crosscut west to connect with the underlay shaft previously alluded to, and at 37 feet a quartz reef was met with; altogether three reefs were cut, said to be one foot, two feet, and 18 inches in thickness respectively; about 130 feet of driving was done on the middle reef to the north, and about 160 feet to the south. The dump shows massive diorite with some slaty bands which probably are near the reef [**5444, 5445**]. Near the north end of the lease there is a flat reef where there is an open cut. South of the main reef there is a small vertical reef about nine inches wide with an ironstone and quartz breccia on the west side of it. Two shafts on the south boundary of this lease show a coarsely crystalline epidiorite.

In G.M.L. 147, THREE COLONIES EXTENDED, Inspector Angove reported that a shaft 63 feet deep had been sunk passing through a quartz reef two feet thick at 23 feet, and another of equal thickness at 52 feet, and that at 60 feet a great influx of water was met with. There was a battery of 10 stamps on Lease 88, and also a Langley Mill, the former was sold and removed, but portions of the latter remain. The Company deposed that they expended £43,000 on the property; Lease 88 became void in 1902. The Missfire became void in 1901, and was subsequently the PRIMROSE, G.M.L. 845. The RESCUE, G.M.L. 875 was also at this time applied for, adjoining the Desirable Extended. The Three Colonies became subsequently in part Q.C. 112 held by Mr. Hopper up to May, 1903, and also Q.C. 140 held by Messrs. Woods and party up to the month of April, 1904.

The following table gives the yield of the Three Colonies Reef, as deduced from official figures:—

Table showing the Yield of the Three Colonies Reef.

Year.	Name and No. of Lease.	Dollied.	Tons crushed.	Tons cyanided.	Ozs. therefrom.	Ozs. from crushings.	Remarks.
1897	Three Colonies 88	...	240·00	...	...	169·85	
1898	Do. ...	...	32·00	...	...	13·00	
1899	Three Colonies 88, 89, 147, M.A. 10	...	62·00	...	...	32·75	
1900	Do. ...	...	16·00	...	...	22·27	
1901	Do. ...	...		...	...		
1902	Q.C. 112 ...	...	42·50	5·50	·95	70·61	State Battery.
1903	Do. ...	sweep'gs 6·60	34·50	15·00	5·21	27·25	State Battery.
1903	Unregd. Q.C. Woods	...	10·00	...	...	3·10	State Battery.
		6·60	407·00	20·50	6·16	338·83	
						6·16	
						6·60	
						351·59	or ·864ozs. per ton.

The Golden Bottle Reef.

The GOLDEN BOTTLE, G.M.L. 112 of 12 acres on the north side of the last, is mostly on the lake bed and has a reef of several feet thickness trending south-east and north-west. An opencut has been made at the edge of the lake on a large reef which appears to be vertical and barren. The old workings are scattered about the lease and out on the lake bed, and are not well defined owing to the lapse of time and drifting sand. Inspector Angove's report indicates that seven shafts have been sunk vertically upon the lease, but none of these are shown on the map; No. 1 was carried down 34 feet; No. 2 was 22 feet with a drive to the south-east of 60 feet; No. 3 was 41 feet and met with a heavy influx of water; No. 4 had been carried down 22 feet with a drive to the eastward of 24 feet, in which heavy water is stated to have been struck; No. 5 shaft 38 feet with an eastern drive of 40 feet; No. 6, 24 feet in depth with a western drive of 6 feet, the shaft struck water at the bottom. There are no returns however from this reef.

The Criterion North Reef.

Nearly half a mile south-easterly of the last was the CRITERION NORTH, G.M.L. 216, of 12 acres, on a reef trending a little south of east and underlaying 75 degrees south, on which two shafts have been sunk and a prospecting shaft on an east and west reef, and a second prospecting shaft on another reef south of it, three or four chains; the size of the reefs was not ascertainable.

The Desirable North Reef.

On the north side of this lease was the DESIRABLE NORTH, G.M.L, 335, of 24 acres, a small north and south reef, the thickness of which could not be ascertained, underlays 60 degrees to east. Three shafts have been put down on it; another outcrop of a north and south reef of considerable size occurs in a gully about a quarter of a mile north. It has a dark coloured quartz, but appears to be barren.

The Moonta Norseman Reef.

The MOONTA NORSEMAN, G.M.L. 449 occupies a ridge of epidiorite rock half way towards the Princess Royal. There is a shaft about 100 feet on a short quartz reef trending north-east and south-west, the thickness could not be escertained [**5440**].

The Golden West Reef.

Nearly one mile east from here is the GOLDEN WEST, G.M.L. 650 on kaolinised ground. At the north corner a shaft was sunk near the track, where there were some broken up portions of a quartz reef carrying 30dwts. values, but the large amount of water and the treacherous kaolin has prevented much prospecting being done. This ground may be worth more attention. The most suitable procedure would be by boring to locate the position of the reef that is probably hereabouts. This position is on the line of

quartz dykes, and there may be a continuation of the line of reef from the Princess Royal in this direction. East of this was the Iona, G.M.L. 644 of 12 acres, which subsequently became Iona, G.M.L. 818, and was voided in December, 1900. This lease may have had a portion of the same reef that was met with in the Golden West.

Table showing the Yield of the Golden West Reef.

Year.	Name and No. of Lease.	Tons crushed.	Ozs. therefrom.	Remarks.
1898 ...	Golden West 650	50·00	52·27	State Battery
1898 ...	Iona 644	44·50	9·50	
		94·50	**61·77**	or ·654ozs. per ton.

The Mary Eileen Reef.

About one and a quarter miles north-easterly from here, at the edge of Lake Cowan, was the Mary Eileen, G.M.L. 929, where a small reef was found, the application of which was withdrawn before survey.

Table showing the Yield of the Eileen Reef.

Year.	Name and No. of Lease.	Tons crushed.	Ozs. therefrom.	Remarks.
1904 ...	Mary Eileen 929	**16·50**	**8·11**	= 7·04 F or ·491 ozs. per ton.

The Princess Royal Sovereign Reef.

About a quarter of a mile south of the Iona was the Princess Royal Sovereign, G.M.L. 893 of 24 acres. Two shafts have been sunk here in kaolin to a depth of 60 feet in search of a continuation of the Princess Royal deep lead. A few chains south-east of these shafts there is a quartz reef outcrop trending south-easterly with an underlay of about 75 degrees to the south-west, on which a shaft has been sunk. This shaft is in the Rienza, G.M.L. 834, of 15 acres, one of the Princess Royal North G.M. Co.'s blocks.

The Princess Royal Reef.

The Princess Royal Reef, which the statistics show to have been one of the principal gold-producing reefs of Dundas, can be followed more or less uninterruptedly for a distance of at least 1,500 feet, though there seems to be good ground for believing it to extend much farther than this. The reef has been followed to a depth of 500 feet vertically below the level of the main shaft in the

Princess Royal lease, and to a depth of 950 feet in the new vertical shaft put down on the Princess Royal Central lease.

The reef has a general north and south strike with an average underlay to the east of 45 degrees; throughout its course it presents the usual variations in thickness which are characteristic of veins of the fissure type.

Parallel to what is called the main reef in the Princess Royal mine is the East reef, which outcrops at a distance of about 200 feet from it. This reef is not traceable to any great extent on the surface, nor does it appear to attain any thickness; it has been proved by mining operations and boring in this lease to a depth of 380 feet vertically below the surface.

On what is evidently the north end of this line of reefs is situated the PRINCESS ROYAL NORTH G.M., which has leases 634, 653, 687, 744, 745, and 634, containing 58 acres 2 roods and 22 perches; to this has to be added the Desirable leases 848, 870, and 915, or 26 acres more—total, 84 acres 2 roods and 24 perches. The shaft on the south boundary of G.M.L. 634 was sunk 70 feet on this reef, found here by costeening; another prospecting shaft was sunk about 150 feet north-easterly of this to a depth of 120 feet; each of these has 200 feet of drives. The main shaft is vertical, and has a depth of 390 feet [**5573**]. No. 1 level is at 250 feet; a cross-cut was put in west, reaching the reef at 114 feet; it was one foot thick here and of poor value; water was struck here. The drive north is 126 feet [**5576**], and to south 152 feet. The jointing of the amphibolite at this level is 55 degrees to the west, but the rock becomes foliated in the hanging-wall of the reef parallel to the latter, which underlays 20 degrees to east [**5574**]. No. 2 level is at 380 feet; the reef is here about 15 feet west of the shaft, and it has a felsite foot-wall; the drive north is 220 feet, and south 325 feet; a little stoping has been done on the former, and there is a winze where a quartz spur joins the reef and which here increases to two feet in width. The reef is very much split up into veins and is of poor value, except at the spur reef, where it was 2ozs. per ton. There is a battery here of 10 stamps. The total expenditure of the company up to March, 1904, is given as £21,285.

The PRINCESS ROYAL G.M. since the end of 1898 has comprised the amalgamated leases 106, 187, and 587, embracing a total area of 51 acres 3 roods and 12 perches; and has been the principal gold-producing mine in the Dundas Goldfield (Fig. 13). Lease 106 was taken up by F. G. Chester and party on 2nd May, 1895. The original workings were on an outcrop of the main quartz reef in the middle of the lease. The general underlay of the reef is about 45 degrees easterly, and general trend north and south. The chute of ore which comprises most of the quartz to over 300 feet depth bifurcates to south-east from the above-mentioned outcrop; this is indicated on Plate I by the stoped portion. No. 7 shaft was used for some time as the working shaft until the main vertical shaft reached 515 feet, after which the two portions of the mine

Photo., W. D. Campbell. Govt. Photo. Litho.

Princess Royal. G.M.L. 106, view looking north.

were connected by the levels driven through the intervening ground. The Eastern Reef is of small extent; its outcrop passes about 25 feet west of the main shaft, and has been worked down to the 200 feet level for a length of 120 feet. It is accompanied by a network of cross reefs. These workings are for the most part in a decomposed and kaolinised greenish felsite rock. There are several dykes of this felsite, all almost perpendicular, traversing the mine in a direction slightly east of north; it is less siliceous than the quartz porphyries, which constitute most of the other dykes in the district, but both varieties are locally called quartzite. This felsite decomposes readily into kaolin, which prevents any outcrop being seen. The dyke appears to have conduced to the deposition of the gold in the reefs where the latter traverse it. The north and central chutes have been stoped for a length of about 100 feet, the former down to the 380 feet level and the latter to the 200 feet level, where it merges into the principal body of quartz termed the south chute. Stoping has been done down to the 380 feet level on this line; in the middle portion of the chute some of the richest quartz has been found where the reef ranges up to 20 feet in thickness. A curiously shaped spur or lens of ore ranging up to 10 feet thick and 130 feet in length occurs between the 220 and 380 feet levels; its middle portion is flat and basin-shaped, and its foot is steep and dome-like. At the 380 feet level the quartz diminishes in quantity and quality, and the drive is being prosecuted southward towards a lens of ore found in the intermediate level above and beyond the main lens. The 500 feet level is clear of the felsite, and is much straighter than any previous one; it is on the lode channel the whole distance, which is not the case in some of the other levels in the barren ground; the quartz is met with in patches, excepting at the foot-wall fork of the reef, where it is strong; a dotted line on the plan shows the zigzag course of this fork at the different levels. A small amount of sulphide ore occurs below the 140 feet depth of the north chute, and below the 220 feet in the south chute. Boring with the diamond drill was commenced in June, 1904, to endeavour to test the locality of the reef in the next 200 feet below the 380 feet. Two bores were also made horizontally east and west. The positions of these bores are shown in Plate 1. The particulars as to the various formations pierced are as follow:—

No. 1 Bore from 380ft. level, at end (66ft.) of east crosscut; angle of depression, 70°.

43ft. to 45ft.—Quartz; assays trace of gold.

To 143ft. 6in.—Schistose amphibolite.

143ft. 6in.–153ft. 4in.—Quartz reef 4ft. thick; assay value, 10 grains; vertical depth about 516ft.

153ft. 4in.–153ft. 6in.—Hard hornblendic amphibolite.

163ft. 6in.–165ft. 6in.—Quartz; trace of gold.

165ft. 6in.–265ft. 7in.—End in very hard amphibolite.

Total depth, 630ft.

No. 2 Bore from same locality; vertical.

To 70ft.—Schistose amphibolite.

70ft.-75ft. 6in.—Quartz reef 2ft. 6in. thick; assay value, 20 grains.

75ft. 6in.-85ft.—End in schistose rock. Total depth, 465ft.

No. 3 Bore from east crosscut, north of main shaft, 380ft. level. Due east; horizontal.

To 51ft.—Light green felsite; assay, 1-2dwts.

51ft.-62ft.—Schistose amphibolite.

62ft.-87ft.—Dark brown felsite.

87ft.-90ft.—Hard amphibolite; fine grained.

90ft.-124ft.—Softer amphibolite.

124ft.-201ft.—Amphibolite.

201ft.-240ft.—Schistose amphibolite.

240ft-241ft.—Quartz; assay value, trace.

241ft.-320ft.—Soft felsite.

320ft.-366ft.—Schistose amphibolite.

366ft.-367ft.—Quartz.

367ft.-391ft.—End in amphibolite.

No. 4 Bore west from No. 7 shaft.

To 48ft.—Amphibolite, with quartz veins highly mineralised.

48ft.-52ft.—Quartz mixed with amphibolite; no values; Jamaica reef (?)

52ft.-112ft.—Amphibolite.

112ft.-116ft.—Brownish rock; highly mineralised lode matter; value, 2dwts. 12grs.

116ft.-140ft.—Hard laminated amphibolite.

140ft.-269ft.—Hard amphibolite.

269ft.-270ft.—Quartz veins.

270ft.-446ft.—End in hard amphibolite.

Nos. 5, 6, 7, 8, and 9 bores are from the same locality, east crosscut, 500ft. level.

No. 5 Bore.—Angle of depression, 65°, bearing due east; total depth, 631ft.

To 95ft.—Schistose, with thin quartz veins.

95ft.-96ft.—Quartz veins; assay value, trace.

96ft.-120ft.—Schistose amphibolite.

120ft.-136ft.—Quartz porphyry.

136ft.-139ft.—Amphibolite.

144ft.—Softer amphibolite.

In progress.

No. 6 Bore.—Angle of depression, 45°, bearing 155°; length, 143ft.; total depth, 601ft.

96ft.–99ft.—Quartz; assaying trace.

143ft.—End in amphibolite.

No. 7 Bore.—Angle of depression, 41°, bearing 34°; length, 175ft.

123ft.—Quartz, and still in quartz at 142ft. Assay values of core: First 13ft., about 3dwts.; next 3ft., 1oz. 1dwt.; next 3ft., 10oz. The drill would at this point be 90ft. north of crosscut and at a vertical depth of 613ft. from surface.

No. 8 Bore.—Angle of depression, 50°, bearing 69°; length, 314ft.; total depth, 705ft.

No. 9 Bore.—Angle of depression, 39°; length, 315ft.; total depth, 700ft.

No. 10 Bore.—Horizontal from end of drive to south, 380ft. level; length, 226ft.; went off line of lode.

The country rock is fine and coarse-grained amphibolite; some of the former, in bore No. 3 [**6038**], was pyritous and very hard. It is massive with jointing to the west 75 degrees, but for about 10 feet adjacent to the reef it is frequently foliated in a direction parallel with the reef, as may be seen in the open-cut adjacent to No. 7 shaft and at the 380 feet level. This foliation does not occur, excepting to a very small extent, along the contact surfaces near the dyke, but is present where the quartz reef has been formed between the amphibolite and the dyke [**5456, 5457, 5459**]. The battery has 30 stamps, and there are 10 cyaniding vats, viz., five settling and five leaching vats of 100 tons capacity each, and three agitating vats of 20 tons, and also two filter presses. The workings of this mine are shown on Plate 1 accompanying this report.

The Princess Royal Central G.M. adjoins the eastern side of the Princess Royal mine and comprises leases 840, 874, 879, 894—being a total 86 acres.

As this Company held the ground of the same reef as the Princes Royal main reef at a depth on its underlay, there were two courses open to them to adopt; either to wait till the workings of their neighbours had shown where and how the reef was, or to exploit it. They chose the latter, and have gone about the proving of their ground in a very energetic and able manner.

The site of the main shaft, which is vertical, is 315 feet east of the 500 feet level of the Princess Royal, which has been driven since this shaft was begun on the 17th February, 1904. Rock drills were employed after 11th June, 1904, and a depth of 841 feet was reached on 17th February, 1905, a year's work, establishing a record for rapidity of sinking in the district. After the first 35 feet of decomposed rock, the hard amphibolite was met with and continued to 340 feet, when a slight change occurred and a forma-

tion at 415 feet. At 573 feet a pyritous vein was cut nine inches thick, which assayed traces of gold [6117]. Water was met with here which caused sores to appear upon the miners employed in sinking below this, in all probability due to the presence of sulphuric acid derived from the decomposition of the pyrites. Another formation occurred at 760 feet with quartz veins assaying, the manager informed me, 15 to 22 grains of gold. On 1st March, 1905, at 870 feet some veins of quartz [6118] were met with underlaying 55 degrees to the east and a short distance below this a felsitic dyke three to four feet thick, with a westerly inclination. The country rock here is similar to that on the hanging-wall of the 500 feet level of the Princess Royal, and continues down to a seven feet quartz reef at 934 feet which, however, did not here show any gold. The shaft was continued to 950 feet, and drives were being started north and south. The north drive shows a reef five feet wide, three feet of which is poor grade and the rest high grade stone. In the south drive the reef is much broken up. The country rock throughout is finely and coarsely crystalline amphibolite.

Princess Royal South G.M. Co. have four leases, 647, 678, 698, and 841, embracing in all an area of 41 acres, that adjoin the south boundary of the Princess Royal G.M., and are evidently on the same line of reefs. The old shaft near the west side of G.M.L. 647 was not accessible at the time of my visit. According to Mr. Catlin's account, it was sunk 76 feet vertically, when some small quartz veins were met with, which underlaid to the east, and they were tried by short crosscuts and a drive, but were all found to be barren. The shaft was continued to 152 feet on the underlay. At 122 feet a 12 inch quartz vein was met with containing a little gold, it however narrowed to a leader and was cut by a felsite dyke from the foot-wall. At 130 feet mineral specimen [736] was obtained; it is very much the same kind of material that forms the dykes of the Princess Royal. This felsite continued for 20 feet, when some rubbly quartz was met with four to five feet thick, with a solid centre, which yielded a little gold. No further work was done here, but the main shaft was sunk vertically to the eastward to intersect this reef, which was met with at 210 feet. The total depth attained by the shaft was 250 feet, at which depth a crosscut was put in westerly 204 feet, and another easterly, which reached the reef at 50 feet where it proved to be very flat (about 10 degrees to east); the reef continued in the crosscut to 74 feet, when drives were put in north 68 feet and south 81 feet respectively. The quartz is somewhat opaque or stony with a green tint, possibly due to an intermixture of felsite with it [5474], and no values were found. The general underlay of the reef is about 45 degrees; work was in progress here at the time of my visit. The adjacent rock is a coarse-grained amphibolite slightly foliated near the reef [5472, 5473]. At the bottom of the shaft there is a small quartz vein nearly vertical, striking 30 degrees west of north. A close, fine-grained diorite [5471] appears here in the form of a laccolite or horizontal sheet; it was evidently intruded into the coarser grained amphibolite [5472]. The dyke rises slightly to the west and at 50 feet in the crosscut,

and forms the whole of the rock in the crosscut to about 150 feet, where a few stringers of quartz occur; work was stopped here on account of the excessive hardness of the rock. A small shaft at the south-west corner of this area is sunk on a similar kind of quartz as is to be seen on the dump of the other old shaft. There have been apparently no crushings by this mine. The expenditure of this company up to June, 1904, was £10,075.

The following figures give, in a tabular form, the yield of the Princess Royal Reef, in so far as such may be deduced from official data :—

Table showing the Yield of the Princess Royal Reef.

Year.	Name and No. of Lease.	Tons crushed.	Cyaniding.		Gold from crushing.	Total.	Remarks.
			Tailings.	Gold.			
			tons.	ozs.	ozs.		
1900	Princess Royal North 634 and 658	20	...	...	32·80	...	
1901	Princess Royal North 634	92·50	...	...	43.76	...	36·06 F
		112·50	...	...	...	76·56	
1897	Princess Royal South 187	358	...	...	640	640	
1896	Princess Royal 106 ...	10	...	...	120	120	
1897	Princess Royal 106, 587	2,074	1,406	837·35	4,151·68	4,989·03	P.R. Coy.
1898	Princess Royal 106, 587, 650	6,136	3,192	1,404·87	9,091·30	10,496·17	,,
1899	Princess Royal 106, 187, 587	11,804·50	3,792	2,409·28	9,327·64	11,736·92	,,
1900	Princess Royal 106, 187, 587	13,071	18,648	7,722·14	10,741·95	18,464·09	
1901	Princess Royal 106, 187, 587	18,233	14,835	4,397·25	13,020·85	17,418·10	
1902	Princess Royal 106, 187, 587	18,073	13,888	2,841·50	17·700·45	29,541·95	
1903	Princess Royal 106, 187, 587	20,357	16,156	2,748·95	21,365·70	28,900·75	
		..	8,969	3,944·05	...		
		...	117	842·05	...		
1904	Princess Royal 106, 187, 587	22,261	17,200	2,380·25	14,406·25	21,665·30	— 17,581·16 F. 2,090·75 Silver
		...	12,563	4,328·10	...		
		...	115	550·70	...		
		112,602·50	110,881	34,406·49	100,642·38	135,048·87 or 1·1993 ozs. per ton	

The Hidden Treasure Reef.

This fairly well-defined reef lies about 1,300 feet north of the large norite dyke which traverses the field in an east and west direction. The reef outcrops on the southern slope of a conspicuous rise to the south-west of the Princess Royal townsite. So far as may be seen on the surface, the reef can be followed for a distance of about 500 feet. Here the HIDDEN TREASURE, G.M.L. 211, of 18 acres, was situated, it was abandoned on the 5th April, 1897, and became subsequently, in part, PRINCE OF THE WEST, G.M.L. 648, of 12 acres. The reef has an east and west course underlying south ;

the main shaft is stated to be 150 feet, with a 40-feet drive, another shaft 25 feet deep, with 80 feet drives and winze 15 feet, and another shaft 47 feet deep; some stoping has been done adjacent to the main shaft. The reef is of small size, but has a good appearance. The country rock is fine-grained amphibolite. The lease was void in October, 1898, and in 1900 became in part Q.C. 59, held by Mr. Denis Duggan; this was forfeited during 1903, and eventually became Q.C. 124, held by Messrs. Stockton and Diack since May, 1903.

The table gives the yield of the Hidden Treasure Reef:—

Table showing the Yield of the Hidden Treasure Reef.

Year.	Name and No. of lease.	Dollied.	Tons crushed.	Tons cyanided.	Ozs. therefrom.	Ozs. from crushings.	Remarks.
1897 ...	Hidden Treasure, 211	...	82·00	...	...	63·30	Bevilaqua
1897 ...	Prince of the West, 648	...	33·00	...	...	25·06	
1898 ...	Do. ...	...	63·50	...	...	57·49	
1899 ...	Q.C., 59	...	15·00	...	...	9·30	Bevilaqua
1900 ...	Do.	...	4·00	...	...	2·15	Do.
1903 ...	Q.C., 124	...	20·50	15·00	3·66	15·98	State Battery
			218·00	15·00	3·66	173·28 3·66	
						176·94	or ·811ozs. per ton

About a quarter of a mile south of this is the norite ridge, which averages three-quarters of a mile wide, in which there are no reefs.

The Federation Reefs.

This small group of reefs, within the boundaries of the 12-acre lease, seem to have returned a fair quantity of gold. The main or north and south reef, upon which most of the work has been done, has only a very short outcrop, and a dip to the east at an average angle of about 20 degrees. The position is about three-quarters of a mile south of the norite and half-a-mile east of the Coolgardie road. The first lease here was the Tommy Atkins, 746, of 12 acres, on the top of the low hill. There are here several small reefs in various directions besides the north and south reef. All have very uncertain courses. The old main shaft is 53 feet on the underlay, with 40 to 50 feet drives, with a winze down another 56 feet. The reef is 12 to 15 inches thick. The lease was forfeited in April, 1900, and subsequently became the Federation, G.M.L. 802, of 12 acres. A vertical shaft was sunk 50 feet to cut the reef deeper, but failed to meet with it, and a drive was being put in towards it at the time of my visit. On the northern cross reef there is a shaft 30 feet vertical and 25 feet on the underlay. There are also several prospecting shafts on cross reefs adjacent to the lease.

The following table gives the yield of the Federation Reefs, the average return from which seems to have been high :—

Table showing the Yield of the Federation Reefs.

Year.	Name and No. of lease.	Dollied.	Tons crushed.	Tons cyanided.	Ozs. therefrom.	Ozs. from crushing.	Remarks.
1899 ...	Tommy Atkins, 746	...	28·00	...	...	7·25	
1900 ..	Federation, 802 ...	...	57·50	...	...	137·62	
1901 .	Do. ...	...	93·00	...	...	122·45	
1901 ..	Do. ...	...	...	18·00	4·66	...	State Battery
1902 ..	Do. ...	...	57·00	...	...	128·91	
1902 .	Do. ...	...	...	25·50	15·63	...	State Battery
1903	Do. ...	...	34·50	...	...	69·78	
1903 ..	Do. ...	...	...	41·50	20·67	..	State Battery
1904 .	Do. ...	...	...	14·00	·11	...	
			270·00	99·00	41·07	466·05	
						41·07	
						507·12	or 1·878ozs. per ton

The Venture Reef.

The VENTURE REEF, so far as may be inferred from an inspection of the surface, has a very sinuous and interrupted outcrop of about 1,200 feet length, with a very varying underlay to the south. This vein, which has a varying thickness from 12 to 18 inches, has been followed to a depth of about 40 feet vertically below the surface, and has proved a good gold producer. It is situated about 30 chains easterly from the Federation; the ground was taken up first as the THULE, G.M.L. 193, of 18 acres, which included two reefs. The southern one has a north-westerly course and underlay to east; two shafts have been sunk upon it. The northern one runs east and south-east sinuously, with a varying underlay up to 55 degrees. There is no record of any crushing from this lease, which became void in December of 1897. The AVELINE, Q.C. 128, held by Thomas and party, was subsequently here on the east and west reef, as well as the Venture, G.M.L. 887 of six acres, when an underlay shaft was put down 40 feet, and driving and stoping done, with very good results.

The table, the data forming which have been obtained from official sources, gives the yield of this reef:—

Table showing the Yield from the Venture Reef.

Date.	Name and No. of lease.	Dollied.	Tons crushed.	Tons cyanided.	Ozs. therefrom.	Ozs. from crushings.	Remarks.
1901	Venture 887 ...	...	12·00	...	...	12·60	State Battery
1902	Do. ...	...	...	8·00	1·25	...	Do.
1903 ..	Do. ...	...	70·00	...	..	66·50	
1903 ..	Do. ...	...	...	58·00	8·05	...	State Battery
1904	Do. ...	8·44	...	...	...	...	= 6·95 F.
1904 ..	Do. ...	...	318·50	...	...	322·63	= 256·09 F.
1904	Do. ...	...	...	192·00	36·95	...	State Battery
1903 .	Q.C. 128, Aveline	...	81·50	43·00	14·20	110·57	Do.
1904 .	Do. ...	...	26·50	36·00	8·78	33·44	= 27·56 F.
		8·44	506·50	337·00	69·23	545·74	
						69·23	
						8·44	
						623·41	or 1·226ozs. per ton

The Lucky Hit Reef.

The LUCKY HIT REEF is another short east and west reef underlying southward, which has been opened by several shafts. The ground was taken up at the south end of the Thule as the LUCKY HIT, G.M.L. 108, of 12 acres. This included two reefs, the Lucky Hit Reef and the northern extension of the Maloney Reef. The latter was met with at the old main shaft, at the south-west corner, 120 feet; it struck the Maloney Reef at that depth, where it was three feet thick, according to Mr. Angove. Three other shafts are each 50 feet in depth, and while no information is available of the workings, the yield of the Lucky Hit Reef may include a return from Maloney Reef, it being impossible to separate the two, as both occur within the boundaries of the same lease, as the stone may not have been separately milled. The northern reef has had two shafts sunk on it, one of them 70 feet deep, together with drives and stoping. The lease became forfeited at the close of 1897, and subsequently in part the KYNETON, G.M.L. 712, of 12 acres. This latter was forfeited in 1899. The northern portion of these two last leases became subsequently in part the KING WILLIAM, G.M.L. 871, of 4 acres 3 roods and 34 perches, which became void in 1904, whilst the remainder was held as PROSPECTING AREA 54. The yield of the Lucky Hit Reef is given in the attached table:—

Table showing the Yield of the Lucky Hit Reef.

Year.	Name and No. of lease.	Dollied.	Tons crushed.	Tons cyanided.	Ozs. therefrom.	Ozs. from crushings.	Remarks.
1897 ...	Lucky Hit 108 ...	...	43·00	...	...	13·50	Bevilaqua
1898 ...	Do. ...	...	63·00	...	...	26·40	
1898 ...	Kyneton 712 ...	...	12·00	...	...	5·40	
1899 ...	Do. ...	...	54·00	...	...	18·25	
1900 ...	Q. Claim ...	...	15·00	...	..	5·00	Bevilaqua
1903 ...	King William 871	...	30·00	...	...	49·10	State Battery
1903 ...	Do. ...	...	...	21·33	5·57		
1904 ...	Prospecting Area 54 ...	...	43·00	...	...	25·30	= 17·86 F. State Battery
1904 ...	Do. ...	...	...	13·00	1·91	...	
			260·00	34·33	7·48	142·95 7·48	
						150·43	or ·578 ozs. per ton

The Maloney Reefs.

About ten chains south of the Lucky Hit lease 108, the principal Maloney reefs, three in number, outcrop strongly and trend about 23 degrees, with an underlay of about 40 degrees to the east.

there are also said to be several cross reefs. These reefs vary from one foot to six feet, and have yielded about ½oz. per ton.

The MALONEY, G.M.L. 56, of 12 acres, adjoined the south end of 108. Mr. Angove's report of 1896 mentions that No. 1 and No. 2 shafts on underlay were 60 feet and 35 feet on a reef four feet wide. No. 3 shaft on a parallel reef five feet to six feet wide was 135 feet vertical and 15 feet on the underlay. It is said that "made ground" was met with in a drive at the 135 feet level, but it seems hardly probable, there may have been some disturbance there due to the quartz porphyry dyke which outcrops about two chains from the shaft. The quartz has a good appearance and the country rock seems much decomposed, judging from the dump (see returns.) The ground was forfeited in September, 1897, and became subsequently the THREE KINGDOMS, G.M.L. 655, of 12 acres, which was withdrawn towards the close of 1899. The northern portion became the Two WILLIAMS, G.M.L. 881, of five acres, and existed as such from May, 1903, to February, 1904, when it and a portion of the GLADSTONE, G.M.L. 256, was taken up as P.A. 57. The southern portion of 655 then became the NEVER DESPAIR, G.M.L. 798, of five acres, and was forfeited in May, 1901. It was subsequently applied for in June of that year as the COME AGAIN, G.M.L. 830. The Come Again existed until August, 1902, when it became void, and was applied for by W. Campbell in 1902 as Q.C. 108. This latter being resumed in January of 1904; part was also held by W. J. Southwell from May, 1903, as Q.C. 125, but was surrendered in the month of September and subsequently held by Haines and Trotter as Q.C. 127, from which there were no returns. This Q.C. 127 was surrendered in October, 1903. Part of the Come Again was, in June, 1903, applied for by Richards and Stephen as Q.C. 132, and abandoned in January, 1904, but was again applied for by Tooth and Gee as Q.C. 142, and subsequently held by Richards and party as an UNREGISTERED Q.C. Part of the Come Again was also occupied in 1903 by Greer and Party as an UNREGISTERED Q.C. I was informed by Mr. Greer that he had two other crushings, besides the one given below, of 10 tons, each yielding about 10 and 3ozs. respectively, but I have not been able to trace them.

At the south end of the Maloney was the LADY ELLEN, G.M.L. 63, of 12 acres, where several shafts were put down to a depth of 50 and 60 feet, to find the southern continuation of the Maloney reefs; but these may follow perhaps the direction of the sweep of the Quartz porphyry dyke. In regard to the Gladstone, G.M.L. 256, of 6 acres, on the east of the Maloney, Mr. Angove mentions two shafts, both vertical, 80 feet and 40 feet, void 17th December, 1897, subsequently part of P.A. 57. In these and GLADSTONE NORTH G.M.L. 462, GLADSTONE EXTENDED, G.M.L. 292, and MALONEY SOUTH, G.M.L. 383, on the eastern side of the Maloney line of reefs, there is apparently nothing of interest to record beyond the quartz porphyry dyke, which sweeps round from the Never Despair to the

King William, and another in the Gladstone Extended. The returns from the Maloney Reefs have been shown in the table below:—

Table showing the yield of Maloney Reefs.

Year.	Name and No. of lease.	Dollied.	Tons crushed.	Tons cyanided.	Ozs. therefrom.	Ozs. from crushing.	Remarks.
1896 ...	Maloney 56 ...	...	50·00	...	...	58·00	
1897 ...	Do. ...	...	122·00	...	...	50·15	Bevilaqua
1897 ...	Three Kingdoms 665	...	62·75	...	...	11·15	
1898 ...	Do. ..	...	30·50	...	...	13·15	
1899 ...	Do. ...	..	10·00	...	...	2·55	State Battery
1900 ...	Never Despair 798	...	112·00	...	...	29·65	
1901 ...	Do. ...	...	16·00	...	...	35·05	State Battery
1901 ...	Come Again 830	...	20·00	13·00	3·05	28·45	
1902 ...	Q.C. 108	...	24·00	53·00	15·01	37·05	
1903 ...	Q.C. 125	...	90·50	...	...	31·35	
1903 ...	Q.C. 132	...	55·50	8·00	7·20	29·86	State Battery
1903 ...	Q.C. 142	...	22·00	...	...	9·30	Do.
1903 ...	Q.C. 172	...	28·00	...	...	16·24	Do.
1903 ...	Unregistered Q.C.	...	54·50	...	...	25·38	Do.
1903 ...	Unregistered Q.C.	...	16·00	...	...	5·20	Do.
1903 ...	Two Williams 881	...	33·00	...	...	16·35	
1904 ...	P.A. 57	...	17·50	...	...	6·80	= 5·60 F.
			764·25	74·00	25·26	405·68	
						25·26	
						430·94 or	·563 ozs. per ton

The Lady Clara Reef.

About three-quarters of a mile south of the Maloney was the Lady Clara, G.M.L. 66, on the north and south line of quartz porphyry on the east side of the hill where the new Government battery is. The dyke is accompanied by a few quartz veins, and at the northern end it is schistose, apparently from pressure. The lease became void in July, 1895, and was subsequently Lady Clara G.M.L. 144, 12 acres. There is one shaft 30 feet deep on the dyke at the crossing of Bevilaqua's abandoned tramway line. This lease was forfeited 3rd August, 1896.

At the south end was the Rising Sun No. 1, G.M.L. 304, of 6 acres, void 19th August, 1896. These became in part Castlemaine, G.M.L. 578, of 24 acres, but became void in October, 1898.

The Thames Reef.

At the north-east foot of the same hill, and crossing the old Buldania track, there is a quartz reef underlaying west, on which Thames, G.M.L. 411, Thames No. 2, G.M.L. 430, and Euclid, G.M.L. 429 are situated, each 12 acres. The reef is near a quartz porphyry dyke. G.M.L. 430 has two shafts which, according to Mr. Angove's report of 1896, are 85 feet on a two-feet reef, and (vertical shaft) 52 feet, with a cross-cut west at bottom. The Euclid, G.M.L. 429, has a shaft 65 feet deep on westerly underlay, and one 10 feet, according to Mr. Angove. There are no crushings recorded from this group.

The Mararoa Reef.

The next line of reef to the eastward is the *Mararoa Reef*, which extends in a north and south direction along the northern portion of the foot of the west front of the Norseman Hill for a distance of three-quarters of a mile; it underlays about 45 degrees to the east; the average thickness is probably four feet, as it ranges up to eight feet in places, and has yielded over one ounce to the ton.

On the northern prolongation of the line of this reef is the COSMOPOLITAN, G.M.L. 321, of 18 acres, with one 25 feet vertical shaft and one 35 feet on the underlay. To the south of the last was the ALL NATIONS EXTENDED, G.M.L. 97, of 12 acres. On the west side of this was the BRITISH NORSEMAN, G.M.L. 442, of 18 acres, in which Mr. Angove states a shaft was sunk on a cross reef, vertically 15 feet and on the underlay 40 feet southerly; also the WEST ALL NATIONS, G.M.L. 613, of six acres. South of No. 97 was the ALL NATIONS, G.M.L. 39, of about 12 acres. Leases 321, 97, 613, and 39 all belonged to the All Nations G.M. Co., by whom it was, in May, 1898, surrendered on consideration of the purchase by the Government of their machinery on lease 97, for the first State battery. From Mr. Angove's account, the main shaft seems to have been 154 feet vertical in part, at least. There are two shafts on the underlay of 40 degrees to east, 90 feet and 46 feet; on the west side were MCCARTHY'S, G.M.L. 175, AND HOMEWARD BOUND, G.M.L. 286, both of 12 acres, in which there are only some small east and west reefs. There is a shaft in each lease, Mr. Angove gives 30 feet as depth of the shaft in McCarthy's and 12 feet in the Homeward Bound; both leases were void in December, 1897.

At the south end of the All Nations is the BETHNAL GREEN, G.M.L. 67, of 12 acres, in which there is a strong body of quartz. The old main shaft is 35 feet vertical and 35 feet on underlay, there are two other shafts 40 feet each and another 65 feet. The Bethnall Green lease became void in October, 1898. It has recently been applied for afresh as BETHNAL GREEN, G.M.L. 939.

The steep spur of the hill at the south end is hard, fine grained amphibolite rock. At the south end of Bethnal Green were the MARAROA EXTENDED N., G.M.L. 298, and EXCELSIOR, G.M.L. 68, these were amalgamated leases, owned by the Excelsior G.M. Syndicate; the reef is four feet wide, and the dumps show it to be accompanied by a schistose amphibolite. There are three shafts on G.M.L. 68, but particulars regarding these are not available; 20 tons only seem to have been crushed, however, and the leases were forfeited about the middle of 1897, as was also No. 1 N. NORSEMAN, G.M.L. 273, adjoining, on the top of the spur.

The MARAROA, G.M.L. 60, was taken up by Goodall and Firth in December, 1894, it passed into the hands of R. Grimes, who sunk three shafts 150, 110, and 80 feet deep respectively; and in May, 1897, it was estimated that there were 800 tons of stone raised, but the lease was forfeited in 1898 without any record of crushing returns being available, the lease became in part MARAROA, G.M.L. 704, of 24 acres, and yielded 3,135 ounces of gold. The lease was sur-

rendered in 1902 and became MARAROA, G.M.L. 852, and has been worked continuously since. The holders, Messrs. Pascoe, Crabb, & Co. also have G.M.Ls. 759 and 912, all of 12 acres each, and own Bevilaqua's battery; the latter had been known from 1899 to 1902 as the Norseman Crushing and Cyanide Works. There are three underlay shafts, the south shaft 145 feet on underlay of about 45 degrees was at first the main shaft, the middle shaft of 100 feet and 40 degrees. The reef is here of two parts, close together at surface and four feet apart below. The first workings were on the western portion. The eastern reef has since proved the best, and is six feet to 10 feet wide, portions showing gold. A remarkable folding of the reef occurs here (or it may be a junction with a large cross reef); these two shafts are connected by a drive on the reef at 150 feet level, the whole of the reef is being crushed at their battery.

The VICTORIA NORSEMAN, G.M.L. 90, on the eastern side, became void in June, 1896, and was subsequently in part VICTORIA NORSEMAN, G.M.L. 500, which was forfeited in January, 1897, and is now in part MARAROA EAST G.M.L. 912. There appear to be no crushings as yet from this ground.

The MARAROA SOUTH, G.M.L. 126, of 12 acres, is on the southerly continuation of the same reef, and has several underlay shafts. Mr. Angove states that the main shaft is sunk 110 feet on underlay. From the 70-feet level a drive goes south 70 feet and north 30 feet, also a crosscut from same depth 35 feet west and 35 feet east. The quartz appears to be very white and of poor value, and there are no records of any crushings. The lease became void in December, 1897, and became subsequently the MARAROA EXTENDED, G.M.L. 759, voided August, 1896; subsequently in part Esperanza G.M.L. 941, not surveyed; still in force. South of this again was the MARORA JUNCTION, G.M.L. 283, of eight acres three roods 22 perches, in which a shaft of 50 feet was sunk; the lease became void on 17th December, 1897.

Table showing the Yield of the Mararoa Reef.

Year.	Name and No. of lease.	Dollied.	Tons crushed.	Tons cyanided.	Ozs. therefrom.	Ozs. from crushings.	Remarks.
1896 ...	Excelsior 68 ...	...	20·12	...	...	11·00	Bevilaqua
1897 ...	All Nations 39 and 97	...	200·00	...	...	67·60	
1900 ...	Unreg. Q.C. ...	...	72·00	64·00	6·08	17·60	State Battery
1901 ...	Do. ...	...	26·00	19·00	3·44	15·29	Do.
1902 ...	Do.	...	37·00	...	...	18·20	Do.
1903 ...	Do. ..	...	92·00	73·30	11·51	12·48	Do.
1904 ...	Do. ...	...	33·00	...	...	11·91	= 7·71 F. Do.
1904 ...	Q.C. 168, Bethnal Green	...	17·50	...	...	4 05	= 3·33 F. Do.
1898 ...	Mararoa 704 ...	...	279·50	...	...	179·75	
1899 ...	Do. ...	...	1,024·00	...	...	736·90	
1900 ...	Do. ...	...	820 00	36·00	6·97	439·90	
1901 ...	Do. ...	...	...	sands ...	1216·07		
				slimes...	56·00		
1902 ...	Do. ...	...	...	1,908·00	500·10		
1903 ...	Do. 852 ...	...	430·00	1,820·00	423·95	131·97	
1904 ...	Do. ...	...	1,530·00	...	...	764·45	=444·59 F. Do.
1904 ...	Do. ...	...	...	1,800·00	807·85	...	= 401·86 Do.
		...	4,581·12	5,720·30	3,031·97	2,411·10	=846·43 F. Do.
						3,031·97	
						5,443·02	or 1·188ozs. per ton

Besides the tailings at the Mararoa battery from stone from their own lease, the Syndicate had many years' accumulated tailings from parcels of stone crushed for the public; these were commenced to be treated in 1902.

Table of result of Cyaniding of Sands at the Mararoa Battery.

Year.	Locality.	Tons.	Ozs.	Remarks.
1902 ...	Various parts of the field ...	1,900	500·00	
1903 ...	Do. do. ...	2,210	526·95	
1904 ...	Do. do. ...	900	189·60	= 133·98 F. and 38·75 Silver.
	Total	5,010	1,216,·65	

Lily and St. Patrick Reefs.

About one-third of a mile east of the Venture and Maloney reefs are a group of leases on the flat, where there is a network of reefs. The northern-most of these leases is the ZIMMERMAN, G.M.L. 412; this and the YATALA, G.M.L. 586 were upon a north and south schistose lode formation about six feet wide; in the latter were several underlay shafts, the western-most being at least 45 feet deep. Inspector Angove's report 1896 states that the lode was six feet wide. On the east side was the GOLDEN DYKE, G.M.L. 377, which Mr. Angove states in 1896 had four shafts, two being on a north and south reef, three feet wide, underlaying east, one shaft being 12 feet vertical and 48 feet on underlay, and two lesser shafts on an east and west reef. According to Mr. Angove none of these leases have had any returns.

THE GOLDEN ALLIE, G.M.L. 376 (also known as the Lucindale) was to eastward of the last, and had an underlay shaft 35 feet on a lode 15 inches wide, and a 20 feet vertical shaft, according to Mr. Angove.

To the south of the last, was the MISS HARRIET, G.M.L. 332, which, having been forfeited in 1898, became subsequently in part the LIVINGSTONE, G.M.L. 694.

To the south of these was the LILY, known also as the GOLDEN BAR, G.M.L. 380, which had a north and south reef on its western boundary, underlaying east and about two feet six inches thick; this was thought by miners to be a reappearance of the All Nations reef. The lease was forfeited early in 1898; and subsequently became the LILY, G.M.L. 695. Two shafts were sunk upon the property; the south one is about 70 feet, and the north about 80 feet vertical and 40 feet on the underlay, stoping was done from a drive at the bottom where the reef thinned out greatly. The Lily became void in 1901, and was subsequently in part Q.C. 123, TWO HILLS, held by J. Garrett for a period of six months ending October, 1903, and a small crushing obtained. Part of this

ground became a twelve-acre lease, the Iris, G.M.L. 908, details of which may be found in the table appended, and is in force. Portions of the Miss Harriet, Livingstone and Lily 695 became the St. Patrick, G.M.L. 702 which was voided in 1900; and subsequently the St. Patrick, G.M.L. 849, at the end of the year 1901, since which date a well defined east and west reef has been worked, underlaying about 23 degrees to south. There are two principal shafts, one about 240 feet on the underlay, and another vertical 135 feet, which cuts the reef at 120 feet. The width of the reef varies from three inches to four feet. Water occurs at 135 feet; slickensided surfaces are prevalent in different parts of the reef; there is a clay hanging wall and an ironstone vein on the footwall. The gold makes where the ironstone touches the quartz. The quartz is mostly of cloudy blue tints with a banded appearance [5929]. Mineral fat is plentiful. A good deal of stoping has been done up to 200 feet east of underlay shaft; the best stone only is taken out instead of being worked systematically.

Table showing the Yield of the Lily Reef.

Year.	Name and No. of lease.	Ozs. Dollied.	Tons crushed.	Tons cyanided.	Ozs. therefrom.	Ozs. from crushings.	Remarks.
1898 ...	Golden Allie 376...	...	6·25	...	...	2·15	
1897 ...	Lily 695	...	26·00	...	...	8·00	Bevilaqua.
1898 ...	Do. ...	...	278·00	...	...	123·50	
1899 ...	Do. ...	...	118·00	...	...	39·38	
1900 ...	Do. ...	...	59·00	...	...	55·50	
1901 ...	Do. ...	...	87·00	14·00	2·28	45·53	
1903 ...	Q.C 123	...	41·00	...	...	37·17	
1904 ...	Do. ...	...	20·50	16·33	2·10	6·70	
		...	635·75	30·33	4·38	320·16	
						4·38	
						324·54	or ·510ozs. per ton.

Table showing the Yield of the St. Patrick Reef.

Year.	Name and No. of lease.	Ozs. Dollied.	Tons crushed.	Tons cyanided.	Ozs. therefrom.	Ozs. from crushings.	Remarks.
1898 ...	St. Patrick 702 ...	...	135·90	...	...	68·48	State Battery
1899 ...	Do. ...	...	55·00	...	...	15·36	
1900 ...	Do. ...	...	...	...	...	...	
1901 ...	Do. 849 ...	..	65·00	50·00	9·66	94·23	
1902 ...	Do. ...	124·61	224·00	...	...	467·92	
				178·00	47·00	...	State Battery
1903 ...	Do. ...	26·20	129·50	...	...	236·80	
				84·25	19·18	...	
1904 ...	Do. ...	...	98·00	...	...	397·90	346·22 F. Do.
1904 ...	Do. ...	32·70	...	...	...	...	28·67 F. Do.
1904 ...	Do. ...	...	...	66·50	34·41	...	Do.
		183·51	707·40	378·75	110·85	1280·69	
						110·85	
						183·51	
						1575·05	or 2·226ozs. per ton.

The Record Reef.

The **Record Reef** is at the south end of a hill one mile south-easterly from Trig. Hill B 23. It is curved in between some quartz porphyry dykes in a north and south direction, and has an easterly underlay of about 65 degrees.

The **Record**, G.M.L. 498, was here, and had a shaft 60 feet, and Mr. Catlin states that a drive was put in at 50 feet, and some stoping done on the reef, which strikes north and south, varies in thickness up to 18 inches, and underlays at 65 degrees to east. There seems to be no record of any crushings; the lease was forfeited 1897. The ground was reapplied for in December, 1898, as **Block 14 Proprietary**, G.M.L. 729, when the shaft was deepened to 100 feet, and drives put in at the bottom, and more stoping done on a portion of the reef bunched up against a quartz porphyry dyke. Q.C. 22 was applied for here by W. R. Gee, in January, 1899, but after holding it for about three months the ground was abandoned. The ground eventually was taken up again as the **Record**, G.M.L. 901. A new shaft was sunk about a chain east of the previous shaft, and a quartz leader two to six inches thick, showing gold freely, was met with, but this thinned out in a drive which followed the reef northward into the above-mentioned quartz porphyry. On panning off the dollied quartz, a brown coloured residue remained with the quartz; this was determined in the Departmental Laboratory to be scheelite [5960], a compound of tungstic acid and lime, which is of some commercial value, if obtainable in sufficient quantity. The reef is said to be traceable at intervals to 15 chains to the northward to the site of Q.C. 7, **New Find**, held by C. W. Perignon and H. Hawkins. A shaft was sunk here to about 80 feet on the underlay. Another Q.C., **Jokaser**, is said to have been held on the same reef.

Southward of the Record is **Quartz Area** 19, where a shaft was sunk on a leader occurring in the westernmost quartz porphyry dyke.

Table showing yield of the Record Reef.

Year.	Name and No. of Lease.	Dollied ozs.	Tons crushed.	Tons cyanided.	Ozs. therefrom.	Ozs. from crushings.	Remarks.
1898 ...	Block 14 Proprietary 729	...	17·00	...	...	31·52	
1899 ...	Do. ...	4·42	71·50	...	...	78·76	
1900 ...	Do. ...	...	...	...	...	—	
1901 ...	Do. ...	...	6·00	...	...	1·15	State Battery
1899 ...	Unregistered Q.C. New Find	...	18·00	...	...	7·95	Bevilaqua and State Battery
1901 ...	Do. ...	...	...	13·50	3·60	...	State Battery
1904 ...	Record 901 ...	...	8·50	5·00	·86	8·55	— 7·04 F.
		4·42	121·00	18·50	4·46	127·93 4·46 4·42	
						136·81 or	1·131 ozs. per ton

Never Mind Reef.

About a quarter of a mile north-easterly on the top of the ridge and about 250 feet from the large quartz porphyry dyke is apparently the site of the NEVER MIND, G.M.L. 120. A shaft was put down and an open-cut made on a reef bearing 345 degrees with an underlay east of 40 degrees, but no particulars are available; the application was withdrawn before survey. There do not appear to have been any crushings recorded from this locality.

The Northern Star Reef.

Half a mile to the south-west of the Record is the northernmost end of the Northern Star reef which extends southerly in a sinuous line for a distance of 5,000 feet, it is on the line of prolongation of the Norseman reef, but there is a blank interval between of 5,000 feet, the characters of the two adjacent ends of these reefs are identical. The underlay is from 43 degrees to 60 degrees to east and has been proved to a vertical depth of 140 feet.

The northernmost lease was the LAST CHANCE, G.M.L. 344, on the line of the valley which crosses here. A shaft 40 feet deep is mentioned by Mr. Angove in his report of 1896; the lease was forfeited in August, 1896. Next was the JESSIE MARGARET, G.M.L. 177, of 18 acres, in which there is a long line of reef outcropping, with four shafts underlaying east; Mr. Angove mentions two shafts in 1896, 40 feet each; the property was forfeited in July, 1896. Next is the GIPSY GIRL, G.M.L. 131, with outcrops of the same reef with two shafts with an average underlay of 60 degrees. The amphibolite to be seen in the dumps is foliated. There is also a cross reef on which there is a small shaft.

Next is the BOHEMIAN, G.M.L. 124, with three shafts; the reef is three feet wide, and Mr. Angove states that in 1896 there was a vertical shaft of 70 feet, with 50 tons of stone at grass. There is a quartz porphyry outcrop on the east side of the reef; this dyke appears to be along the same line along which the quartz reef was subsequently formed; both have probably contributed to the foliation of the adjacent amphibolite. Next is the SUDDEN NORSEMAN, G.M.L. 44, on which a good deal of work was done by the Sudden Norseman and Macedonian G.M. Co., this lease being amalgamated with the MACEDONIA, G.M.L. 139, which adjoins it on the east. The workings were inaccessible at the time of my visit. There are five shafts, two vertical 86 feet and 92 feet, connected by a drive at bottom, a third vertical shaft 6 feet by 3 feet to 125 feet, and two underlay, which are mentioned by Mr. Angove, who reports that one of the latter is 80 feet deep, and on a cross reef four feet wide. The amphibolite in the shaft on the boundary between the two leases shows in places a modification towards siderite or spathic iron [**6025**], *see* return for 1897. Both these leases became void in August, 1898. The G.M.L. 44 became the ST. PATRICK EAST,

G.M.L., 895 of six acres, in 1903. Next southerly was the Morning Star, G.M.L. 54; it has several shafts on the underlay of the main north and south reef from 210 to 150 feet in decomposed rock. This was forfeited in March, 1898; subsequently the Gift, G.M.L. 706, which existed as such until November of 1900, when it became subsequently the Northern Star, G.M.L. 821, which is still in force. The reef has well-defined walls, at the south end of the lease it is three to five feet thick. From three inches to six inches of the footwall side has thin laminated quartz [5990], which carries visible gold; there is very little pyriteous stone, which occasionally carries a little carbonate of copper. The chute of pay ore dips in an irregular manner to the north, only the richer portions of the stone being raised, so that the stoping is mostly irregular. To the south of this was the Scandinavian, G.M.L. 151. Mr. Angove states that one shaft was sunk 85 feet vertically and 40 feet on easterly underlay, the reef in bottom being two feet six inches wide, and another shaft 80 feet on the underlay. Having been forfeited in November 1898, it eventually became in part the Glasgow, G.M.L. 727, from which some small crushings were obtained, which may be found in the table appended. The Glasgow was forfeited, in 1899, when it then became the Scandinavian, G.M.L. 796, from which a small crushing was obtained. The reef appears to cut out here, and although a number of leases were taken up on the probable line of reef no trace of it has been found between this and the Norseman No. 1 North, about 30 chains to the south.

The following table gives the returns from the Northern Star line of reef:—

Table showing the Yield of the Northern Star Reef.

Northern Portion.

Year.	Name and No. of Lease.	Ozs. dollied.	Tons crushed.	Tons cyanided.	Ozs. therefrom.	Ozs. from crushings.	Remarks.
1897	Bohemian, 124 ...	...	17·50	...	...	10·00	Bevilaqua.
1896	Jessie Margaret, 177	...	24·00	...	...	4·00	
1897	Sudden Norseman, 44, 139	...	249·00	...	...	143·00	
1899	Q.C. 27, 44 ..	...	77·00	...	...	8·60	State Battery
1899	Unregd. Q.C., on 44	...	22·00	...	...	5·50	Bevilaqua.
1899	Do. ...	...	90·00	...	...	33·55	State Battery
1901	Unregd. Q.C., Riddler, on 44	...	18·00	...	...	11·40	State Battery
1901	Unregd. Q.C., Hunter, on 44	...	12·00	...	...	4·70	State Battery
1901	Unregd. Q.C. Morgan, on 44	...	18·00	13·00	5·09	8·00	State Battery
1902	... ...	...	...	...	...	...	
1903	Q.C. 127 ...	...	29·50	...	...	5·45	State Battery
			557·00	13·00	5·09	231·20	
						5·09	
						239·29	or ·429 ozs. per ton.

Table showing the Yield of the Northern Star Reef—continued.

SOUTHERN PORTION.

Year.	Name and No. of Lease.	Ozs. Dollied.	Tons crushed.	Tons cyanided.	Ozs. therefrom.	Ozs. from crushings.	Remarks.
1897 ...	Morning Star, 54	...	239·00	...	...	70·55	Bevilaqua.
1898 ...	Gift, 706 ...	...	196·00	...	...	81·68	
1199 ...	Do. ...	...	472·00	...	...	348·45	
1900 ...	Do. ...	...	20·00	...	...	3·56	
1900 ...	Do. ...	...	...	118·00	19·66	...	State Battery
1901 ...	Northern Star, 821	...	149·00	...	...	105·87	
1902 ...	Do. ...	190·65	112·50	...	...	160·98	
1902 ...	Do. ...	...	...	292·00	51·97	...	State Battery
1903 ...	Do. ...	86·80	177·50	...	...	324·75	
1903 ...	Do. ...	...	...	89·25	23·63	...	State Battery
1904 ...	Do. ...	...	100·50	...	...	325·20	= 264·92 F.
1904 ...	Do. ...	143·27	...	...	...	...	= 115·33 F.
1904 ...	Do. ...	...	...	87·08	37·00	...	State Battery
1898 ...	Glasgow, 727 ...	...	20·00	...	...	8·50	Bevilaqua.
1899 ...	Do. ...	...	34·05	...	...	29·67	
1899 ...	Scandinavian, 796	...	14·00	...	...	9·25	State Battery
1900 ...	Do. ...	...	20·00	...	...	2·36	State Battery
		420·72	1,554·55	586·33	132·26	1,470·82 132·26 420·72	
						2,023·80	or 1·302 ozs. per ton.

The Norseman Reef.

The Norseman Reef outcrops along the west side of the Norseman Hill for a distance of 7,000 feet underlying at an average angle of 45 degrees to the east, and has been proved to a vertical depth of 400 feet. The reef is of considerable thickness throughout, ranging up to eight feet in leases 19 and 21. The chutes of quartz are mostly horizontal, and extend for 400 and 500 feet in the workings at the southern end. The quartz is mostly very white where the reef is large, but it is well mineralised in the Viking workings where the best values have been hitherto obtained. The leases along this reef are taken in sections, for the sake of convenience of reference to the tables of crushings.

At the north end are the NORSEMAN No. 1 NORTH, G.M.L. 16, and the NORSEMAN No. 1 NORTH BLOCK WEST, G.M.L. 482, both of 12 acres; these were amalgamated, and both at a later date, with the Mt. Barker Reward G.M. in November of the same year, and designated the New No. 1 North Norseman G.M. Co. The North end of the reef has been generally considered to be cut off abruptly, but I did not find this to be the case, the quartz in the lower levels tapering out into seams of ironstone and oxidized schist, the point of ending dipping to the north. The reef is mostly from one to three feet thick, but averaging about two feet. The main shaft is 310 feet on an underlay of about 35 degrees flattening out to 25 degrees at the bottom; there are levels of 103, 200 and 300 feet. The south

shaft is 180 feet deep. North of the shaft the reef is about three feet thick, this is the north chute [5914]. North of this it narrows and becomes vuggy, the cavities being five or six inches wide and many feet long, partly empty, with siliceous sinter ramifying through them [5912], the reef then tapers out dipping north. South of the main shaft it is again two feet six inches thick, and a break of three to eight feet occurs caused by a fold in the reef, the stone then makes again forming a south chute. Their dip to the north is about 35 degrees. The pay ore is mostly confined to three feet or four inches of the underlay side of the reef, as in the Morning Star. The reef appears to have followed the course of an intrusive porphyry [5913] dyke one foot to two feet thick. It occurs in the hanging wall of the reef south of the main shaft and in the footwall to the north of the shaft; the dyke has been found to be an indicator of gold in the reef. The country rock is amphibolite, somewhat schistose near the reef [5915]. The mine is being worked on a 5 per cent. tribute. A plan of the mine should be in existence but I was not able to find its whereabouts.

The following table gives the total gold yield of the portion of the Norseman reef:—

Table showing the yield of the Norseman Reef (part).

Year.	Name and No. of lease.	Ozs. dollied.	Tons crushed.	Tons cyanided.	Ozs. therefrom.	Ozs. from crushings.	Remarks.
1897 ..	Norseman No. 1 (North) 16	...	501·00	...	...	509·05	
1898 ..	Norseman No. 1 (North) 16, 482, 685	...	1,182·00	...	...	529·00	
1899 ...	Do.	...	891·00	...	...	475·95	
1900	Do.						
1901 ..	Do.	...	489·00	...	...	438·39	
1902 ..	Norseman No. 1 (North) 16	...	258·50	...	...	104·17	
1902 ...	Do.	...	...	243·50	25·10		
1903	Do.	7·55	179·00	...	...	202·85	
1903 ...	Do.	...	...	97·33	16·26		
1904	Do.	...	91·00	...	...	118·74	= 93·69 F. State Battery = 2·95 F.
1904	Do.	3·75	...	90·25	18·69	...	
		11·30	3,591·50	431·08	60·05	2,378·15 60·05 11·30	
						2,449·50	or ·682 ozs. per ton.

Next is the NORSEMAN, G.M.L. 15, where L. Sinclair discovered this reef in July, 1894, and which was forfeited in August, 1899. The lease surrounds his REWARD CLAIM No. 3 on three sides. The two properties were worked jointly, together with the NORSEMAN WEST, G.M.L. 149 on the west side. The workings were inaccessible at the time of my visit. There are three principal shafts which Mr.

Angove states had been sunk on a reef three feet thick. The main shaft is 280 feet on the underlay, with drives at the 50-foot level, but very little stoping is said to have been done. There are several other minor underlay shafts on this reef. The quartz is mostly very white. The northern portion became the NORSEMAN, G.M.L. 758, but was voided in August of 1901, and subsequently became Q.C. 93 held by W. R. Pybus from August of 1901 and resumed in January, 1904. The southern portion of G.M.L. 15 became the GOLDEN CALF, G.M.L. 761, from September of 1899, and the Reward Claim became the NORSEMAN REWARD, G.M.L. 740, from April of that year; it was forfeited in November and became the PRISCILLA, G.M.L. 792, from December until it subsequently became in part Q.C. 74 held by T. C. Ellis from October, 1900, to its surrender in November, 1903. The yield of this portion of the Norseman Reef is given in detail in the table below:—

Table showing Yield of the Norseman Reef (part).

Year.	Name and No. of lease	Dollied.	Tons crushed.	Tons cyanided.	Ozs. therefrom.	Ozs. from crushings.	Remarks.
1897 ...	Norseman 15 ...	...	238·00	...	...	130·70	
1898 ...	Norseman G.M. Co., N.L., 15,149	...	128·00	...	...	40·03	
1899 ...	Norseman 15,149	...	30·00	...	...	12·80	
1901 ...	Q.C. 93	...	24·00	36·00	6·52	12·60	State Battery
1901 ...	Q.C. 95	...	9·00	...	...	2·00	Do.
1900 ...	Golden Calf 761 ...	...	92·00	...	...	74·15	
1900 ...	Unregd. Q.C. Pybus, 761	...	12·00	...	...	4·85	Do.
1901 ...	Unregd. Q.C. Pybus, 761	...	...	17·00	2·68	...	Do.
1901 ...	Unregd. Q.C., C. Thomas	...	44·00	8·00	·69	17·87	Do.
1901 ...	Unregd. Q.C., Happy-go-Lucky, McAndrew	...	6·50	...	...	9·72	Do.
1900 ...	Unregd. Q.C., Union, Knive	...	10·00	...	...	5·30	Do.
1901 ...	Q.C. 66 and 92 ...	...	183·00	41·00	6·16	87·18	Do.
1898 ...	Norseman Reward, 740	...	110·00	...	...	27·56	Bevilaqua
1899 ...	Do. ...	...	191·51	...	...	118·77	State Battery
1899 ...	Priscilla 760 ...	...	40·00	...	...	81·70	
1900 ...	Do 792 ...	...	68·50	...	...	35·45	
1900 ...	Q.C. 74, on 792 ...	...	12·00	8·00	·97	6·88	Do.
1901 ...	Do. ...	...	—	—	—	—	
1902 ...	Do. ...	...	..	22·50	3·02	...	Do.
1903 ...	Do. ...	...	146·00	...	...	75·29	Do.
			1,434·50	132·50	20·04	742·85	
						20·04	
						762·89	or ·5318ozs. per ton

The next lease on the same line of reef is the NORSEMAN No. 1 SOUTH, G.M.L. 17, which was held by the Royal Dane G.M. Co. It has a commanding situation on the top of the Norseman Hill. Quite a network of quartz porphyry dykes occurs at the north end of the lease, and the reef takes a sharp bend due evidently to this cause,

the dykes being prior origin to the quartz. There are three shafts of about 45 degrees on the underlay. The middle one is the main shaft, but the workings are inaccessible. Mr. Catlin states that the depth is 320 feet, and that the reef was of large size all the way down, and is five feet at bottom of the shaft; a little water, about 400 gallons a day, was making at that depth; at 120 feet a drive was put in 34 feet north. The south shaft was put down 70 feet for prospecting purposes. The north shaft is 200 feet with drives at 50 feet level, 103 feet south and 187 feet north. In the south drive the reef is eight feet or nine feet wide; at the bottom of the shaft the reef is eighteen inches. The quartz is very white and of low grade but more pyritous lower down, as is also the country rock, which is similar to that further north.

This lease was amalgamated with the NORSEMAN No. 1 SOUTH BLOCK CLAIM, G.M.L. 57, but was voided in October, 1899, and was subsequently the CELT, G.M.L. 776, which became forfeited in July, 1900.

The crushings from this portion of the reef, the details of which are shown in the table below, show an average of about one half an ounce per ton.

Table showing Yield of the Norseman Reef (part).

Year.	Name and No. of lease.	Dollied.	Tons crushed.	Tons cyanided.	Ozs. therefrom.	Ozs. from crushings.	Remarks.
1897 ...	Norseman No. 1 South 17, 57	...	78·00	...	...	26·30	
1898 ...	Do. ...	...	250·00	...	...	45·95	
1899 ...	Do. ...	...	—	—	—	...	
1900 ...	Do. ...	...	..	—	97·29	...	
1900 ...	Celt 776	...	34·00	...	...	10·90	
1900 ..	Q.C. 65	...	31·00	...	...	17·91	State Battery
1901 ...	Govt.	...	20·00	...	...	5·28	Do
1901 ...	Q.C. 96 and 101 ...	...	45·60	13·00	2·91	13·50	Do.
1902 ...	Do. ...	...	21·50	...	...	11·63	Do.
1902 ...	Unregd. Q.C., Thomas	...	17·50	...	...	27·75	Do.
		...	498·50	13·00	100·20	159·22	
						100·20	
						259·42 or ·5204 ozs. per ton	

Southward from the Celt, the Norseman reef is to be seen for nearly a mile in the Norseman G.M. Co.'s leases, whose 12 leases total 180 acres 1 rood 7 perches; these were mostly taken up in August, 1894, and were amalgamated with the United Scotchman Co. in July, 1897, which company held three leases—22, 24, and 103 (47). The reef is a fine body of stone, but has proved to be of low grade. The mine practically ceased operations in 1901, and it is at

present being worked by a few tributers, who appear to be satisfied with their proceeds, so that this should be a good indication for the future resuscitation of the mine. The quartz is mostly white and slightly blue in tint without much pyrites except at the bottom of the Viking lease workings. There is a considerable amount of silver present in the reef, apparently due to the presence of galena. Calcite occurs frequently [**5972**], associated with the quartz [**5974**]; mineral fat [**5993**] occurs near the main shaft, in addition to small quantities of asbolite. The country is amphibolite [**5975**], which, as is usual about here, is slightly schistose or foliated near the reef. The workings of this mine are shown on Plate II.

The following extract is from page 58 of Bulletin No. 6, by Mr. E. S. Simpson, regarding a sample of this mineral fat collected by the Government Geologist, some years ago :—

"*Mineral fat.*—A clay having when freshly extracted the consistency of tallow is found in vughs in the reef at the Norseman Gold Mines, Ltd., Norseman. It is faintly greenish in tinge when fresh and moist, but on exposure to the air changes in colour to brown and loses water rapidly, becoming first waxy and then dry and granular in consistency. Its composition was found to be :—

	Wet Mineral.	Dry Mineral.
Water H_2O lost over sulphuric acid	49·17	...
„ „ lost on subsequent ignition	9·80	19·08
Silica, SiO_2	20·30	39·53
Alumina, Al_2O_3	18·03	35·11
Ferrous Oxide, FeO	·44	·86
Manganous Oxide, MnO	Trace	Trace
Lime, CaO	·15	·29
Magnesia, MgO	·22	·43
Potash, Ka_2O	·05	·10
Soda, Na_2O	2·36	4·60
	100·52	100·00

"This would correspond to the formula $Al_2O_3 \cdot 2SiO_2 \cdot 3H_2O + 15H_2O$.

"The formulæ given by Dana to the only four minerals approaching this in composition, are:—

Halloysite ...	... $Al_2O_3 \cdot 2SiO_2 \cdot 2H_2O + nH_2O$; or
	$Al_2O_3 \cdot 2SiO_2 \cdot 3H_2O + nH_2O$
Newtonite ...	... $Al_2O_3 \cdot 2SiO_2 \cdot 4H_2O + H_2O$
Montmorillonite	... $Al_2O_3 \cdot 4SiO_2 \cdot H_2O + nH_2O$
Kaolinite ...	... $Al_2O_3 \cdot 2SiO_2 \cdot 2H_2O$

"The Norseman mineral agrees exactly in formula with halloysite, although in outward appearances it resembles more closely some forms of montmorillonite."

The northern leases 19, 20, and 21 were worked by three adits to which underlay shafts connected. In the SYDNEY NORSEMAN, G.M.L. 20, the upper adit is 550 feet along the line of reef, and passes through a quartz porphyry dyke; the reef ranges up to five feet six inches thick. The quartz is blue white, and slightly ferruginous in places with occasional black incrustations, which has been determined in the Departmental Laboratory to be asbolite, a cobaltiferous manganese oxide [**5971-5973**]. The reef ranges up to five feet six inches thick; a little stoping has been done between the adit and the surface, where the reef bifurcates. In the CACHUANCA*, G.M.L. 19, the middle adit cross cuts to the reef 130 feet, and a drive then follows the reef about 300 feet north and south, passing through several quartz porphyry dykes. The quartz is whiter here, and is from three to seven feet wide in the south drive, and stoping has been carried to the surface. In the HARDY NORSEMAN, G.M.L. 21, the lower adit is 500 feet long; it crosses several quartz porphyry dykes. The reef is up to eight feet thick, a whip shaft and also winze goes down about 24 feet below the adit, and stoping has been done to the surface, quite a rich patch having been found here by the tributers. A small fissure occurs here, dipping about 32 degrees to the north, with nodules of magnesite in it; possibly some of the gold may have been of secondary origin [**5970, 5974**]. The company's main shaft is on the MILDURA NORSEMAN, G.M.L. 18, and is 550 feet on an underlay of about 45 degrees, making a vertical depth of 390 feet. The bulk of the workings are in the oxidized zone, and above the 200 feet level. They extend 300 feet north, and 500 feet south to the Scotchman shaft, and most of this is stoped. The chute dips slightly to the south. The average width of the reef here is 3 feet 6 inches. The reef intersects several quartz porphyry dykes; one in the drive south of the shaft is slatey [**5969**], and another north of the shaft is pyritous and of a greenish colour. Between the 200 and 400 feet levels poor values only were obtained; below this, however, they improved. The lower portion of the shaft was inaccessible to me on account of water, which is only soakage from the surface. Mr. Catlin's report states that there is 3 feet thickness of quartz at the bottom. Between these and the next workings in the Viking Norseman a large dyke of quartz porphyry occurs, with offshoots on its southern side. A split in the reef also occurs south of the dyke, and the westerly arm has been worked for a short distance. The VIKING NORSEMAN, G.M.L. 26, was taken up by A. Forbes and party in September, 1894, and it passed into the hands of A. L. Simon, who sold it to the Norseman G.M., Ltd., in March, 1896, for the sum of £10,000. The Viking shaft has a depth of 574 feet on underlay, or a vertical depth of 415 feet. The principal workings extend north 550 feet, and range down to 380 feet depth at the shaft, with stopes on the chute of ore. The oxidized zone also takes a dip here, showing that this is the cause of the erosion of the gully above in the hillside. The reef ranges from a few inches to 5 feet,

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* A misspelling of *Cachucha*, the name of a Spanish dance.

and probably averages 2 feet; it has frequent inclusions of country rock. The quartz is here of higher value than elsewhere in the mine, and shows gold in places, and is very pyritous in the lower levels. A £ for £ subsidy was granted by the Government towards the deeper sinking of this shaft, the intention being to go down to 700 feet, but only 124 feet was so sunk.

In the Annual Report of the Geological Survey for the year 1900, p. 26, the Government Geologist reported as follows:—

"A careful inspection of the Viking workings was made, and especial attention paid to the reef in its lower levels. At 440 feet the reef consisted of about three feet of quartz, carrying a small quantity of pyrites and galena. During my visit the shaft was deepened about four or five feet to enable me to see the character of the reef. The face showed about three feet of quartz, carrying sulphides of iron, zinc, and lead. An unsophisticated sample of the whole face, collected under my own supervision, yielded in the mine laboratory a free milling value of about 12dwts. of gold to the ton. A fire assay of the more highly mineralised portions of the same stone yielded, in the official laboratory in Perth,—

Gold	1oz. 0dwts. 9grs. per ton.
Silver	1oz. 2dwts. 0grs. per ton.

"The relatively large proportion of galena in the sample may be held accountable for the high silver contents. Free gold shows in some of the stone from the face, and specimens are now in the possession of the Department."

and again in the report for 1901, p. 20:—

"Norseman Gold Mines, Limited.—As alluded to in my report of last year, financial assistance was rendered to this company, to enable them to explore the deep levels by sinking the Viking shaft from 450 feet to 700 feet. The following table gives the particulars of assays made in the Departmental Laboratory as the work proceeded:—

Lab. No.	Depth in feet.	Assays.
3020	460	Gold, 20grs. per ton; silver, 2dwts. 11grs. per ton.
3021	470	Gold, trace; silver, 2dwts. 11grs. per ton.
3022	480	Gold, trace; silver, *nil*.
3023	490	Gold, trace; silver, 2dwts. 11grs. per ton.
3024	500	Gold, 1oz. 16dwts. 18grs. per ton; silver, 3ozs. 19dwts. 5grs. per ton.
3025	510	Gold, 2dwts. 11grs. per ton; silver, 15dwts. 12grs. per ton.
3026	520	Gold, 20grs. per ton; silver, 1oz. 3dwts. 16grs. per ton.
3268	530	Gold, 20grs. per ton; silver, 20grs. per ton.
3269	540	Gold, 20grs. per ton; silver, trace.
3270	550	Gold, 3dwts. 6grs. per ton; silver, 4dwts. 22grs. per ton.
3271	560	Gold, trace; silver, *nil*.
3272	574	Gold, 20grs. per ton; silver, 20grs. per ton.

The table appended gives details of the crushings of this portion of the Norseman Reef:—

Table showing the Yield of the Norseman Reef (part).

Year.	Name and No. of lease.	Dollied.	Tons crushed.	Tons cyanided.	Ozs. therefrom.	Ozs. from crushings.	Remarks.
Previous to 1897	United Scotchman G.M., 22, 24, 239	...	1,694	...	...	1,602	
[illegible] ...	Do. do. ...	...	1,628	...	...	1,532·70	
[illegible] ..	Norseman G.M. Co., 18, 19, 20, 21, 26, 48, 94, 101, 103, 115, 116, 138, 235, 236, 611	...	2,499	...	...	2,854·68	
[illegible] ..	Norseman G.M. Co., 12, 18, 20, 21, 22, 24, 25, 26, 48, 94, 101, 102, 115, 116, 138, 235, 236, 611	...	9,584	...	...	10,148·28	
[illegible] ...	Norseman G.M. Co., 18, 19, 20, 22, 24, 26, 48, 94, 101, 115, 116, 138, 235, 236, 239, 611	...	24,655	...	...	10,755·08	
[illegible] ..	Do. do. ...	...	24,331	...	...	8,471·44	10,821·01
	Do. do. ..	...	...	10,302	2,349·57	...	
[illegible] ...	Do. do. ...	...	11,424	...	...	3,735·21	7,366·50
	Do. do. ...	...	...	18,699	3,631·29	...	
[illegible] ...	Norseman G.M. Co., 18, 19, 20, 21, 22, 24, 25, 26, 48, 116, 138, 611	...	1,983	...	...	1,897·41	4,631·31
	Do. do. ...	...	...	19,152	2,733·90	...	
[illegible] ...	Do. do. ...	...	1,355·5	...	...	916·86	2,137·34
	Do. do. ...	...	...	7,279	1,220·48	...	
[illegible] ...	Do. do. ...	...	155·5	...	...	79·86	— 66·50 F. 2·00 Silver
	Do. do. ...	...	...	441	128·38	...	— 71·49 F. 46·53 Silver
		...	79,309·0	55,873·0	10,063·62	41,993·52 10,063·62	
						52,057·14	or ·6563 ozs. per ton

The Royal Standard Norseman Reef.

To the west of the Viking was the Royal Standard Norseman, G.M.L. 100, of 12 acres, in which there is a reef north-east and south-west about two feet six inches thick at outcrop, underlaying 58 degrees southerly, on which a shaft has been sunk. This may be one of the branches into which the Norseman reef appears to split up. The property was forfeited in October, 1896, and subsequently became the Royal Standard, G.M.L. 599, on which a shaft 40 feet was sunk. No returns have been obtained from this reef.

The Ophir Reef.

South of this was the Ophir Reef, a cross reef which has been traced for about 1,800 feet to the south end of the Valkyrie. It underlays south about 55 degrees, and has yielded good values. At the western end was the Ophir, G.M.L. 98, in which three underlay

shafts have been sunk in addition to a vertical shaft; according to Mr. Angove, No 1 is 78 feet, with drive east 34 feet and west 46 feet; the lode is from 18 inches to 20 inches in the east drive and two feet six inches in the west. No. 2 shaft west is 70 feet on underlay. No. 3 is 30 feet on underlay, the reef in bottom being two feet six inches wide; on the north boundary a shaft is down 20 feet on another reef. The Ophir was forfeited in March, 1898, it subsequently became the NEW OPHIR, G.M.L. 707, but was abandoned in April of the succeeding year. From April, 1899, Q.C. 38 was held by M. Kiwru, but was five months later the OPHIR, G.M.L. 847, was subsequently taken up and held from October, 1901, to to July, 1902.

The reef then passed into the OLD SAXON NORSEMAN SOUTH, G.M.L. 30, which is traversed by a small north and south reef with four shafts, which may be a spur of the Norseman reef. Mr. Angove states that one shaft is 40 feet vertical and 90 feet on the underlay, and that the reef is one foot wide, the other shaft is 40 feet, with a drive 240 feet, and two other shafts 25 feet and 35 feet.

Next adjoining was the PALPARAIA NORSEMAN, G.M.L. 110, in which there is an underlay shaft 40 feet Both these two properties became in part the SUSSEX, G.M.L. 627. Records show that the main shaft intersected the reef at 130 feet, and at 170 feet water was met with which stopped further sinking. The Sussex was voided in October, 1898. South of this was the SOVEREIGN, G.M.L. 785, which after being voided in September, 1900, subsequently became the SOVEREIGN, G.M.L. 826, in which several underlay shafts were sunk on the Ophir reef; this lease ceased to exist in August, 1902. The yield of the various holdings on the Ophir reef is given in detail in the table below:—

Table showing Yield of the Ophir Reef.

Year.	Name and No. of lease.	Dollied.	Tons crushed.	Tons cyanided.	Ozs. therefrom.	Ozs. from crushings.	Remarks.
Previous to 1897	Ophir 98	...	118·00	...	...	400·00	
1897 ...	Do.	...	504·75	...	...	371·00	
1898 ...	New Ophir 707 ...	...	38·00	...	...	24·80	
1199 ...	Q.C. 38	...	13·00	...	...	7·75	State Batte[ry]
1901 ...	Ophir 847	...	8·00	...	...	10·45	
				6·00	2·81	...	Do.
1900 ..	Sovereign 785	...	19·00	...	...	29·15	
1901 ...	Do. 826	...	102·00	...	...	99·20	
				23·00	7·25	...	Do.
1902 ...	Do.	...	38·00	...	...	29·76	
				34·00	8·02	...	
			840·75	63·00	18·08	972·11	
						18·08	
						990·19	or 1·1777 ozs per ton.

Valkyrie Reef.

About seven chains east of the Viking Norseman is the north end of the Valkyrie Reef which has a north and south course of about 1,000 feet underlaying east, but at a somewhat flatter angle than the Norseman reef; it has been tested to a vertical depth of 140 feet and has a good body of stone but is irregular and patchy.

Three shafts have been sunk on it in the No. 1 St. Agnes Extended, G M.L. 113. A cross reef also occurs where the gully crosses the main reef line. The property subsequently became in part Q.C. 115, a crushing from which is included in the table with the Agnes Venture Reef.

The next lease to the south on the Valkyrie reef was the St. Agnes, G.M.L. 29, taken up by Mr. Holman in September, 1894. This and the St. Agnes South, No. 1, G.M.L. 35, were held by an English Company, St. Agnes Gold Reefs, which was floated at the end of 1895. To these were added the St. Agnes Block, G.M.L. 189, in October, 1896, the St. Just, G.M.L. 483, the Bonanza, G.M.L. 36, and the Bonanza Block, No. 1, G.M.L. 480. These two last, however, were on the Bonanza Reef, which is an east and west reef and will be described next. They were forfeited in May 1901. Any gold that may have been obtained from these two leases at this period was merged into the yield of the Valkyrie Reef.

A line of pipes was laid down to Lake Cowan and a battery of 10 stamps erected; crushing was commenced at the end of 1897. The Company stated in 1898 that they had spent £23,000 on the property and had done 803 feet of sinking and 728 feet driving. In 1898 the Company had to go into liquidation, and the two first-named leases were forfeited in October, 1899, and the St. Just in June, 1899, and the two last in December, 1898. Leases 29, 35, and 189 became in part the Viking South, G.M.L. 778. Evidence was given before the warden in December, 1900, that the mine had four shafts 265 feet, 75 feet, 40 feet, and 108 feet, with 750 feet of main drives and 2,500 tons of stone stoped out; the stone so far had yielded only poor results. The property was, in May, 1901, forfeited. It subsequently became in part Valkyrie, G.M.L. 831, of five acres, which was amalgamated, in December, 1903, with Valkyrie North, G.M.L. 853, Valkyrie Extended, G.M.L. 880, Valkyrie West, G.M.L. 886, under the name of the Valkyrie G.M. Co. The workings of this Company were in progress at the time of my visit, and are shown on Plate 4. There are several underlay shafts along the outcrop of the reef, the main shaft is at the south end of G.M.L. 29. At the 60-feet level of this shaft, the underlay is 40 degrees and it gradually lessens as depth is increased until, at 240 feet, it is only 15 degrees. The reef is very contorted and varies greatly in thickness from five feet to a few inches. The gold occurs in bunches and appears where the reef has broken through the quartz porphyry dykes or where the quartz porphyry forms the hanging wall [**5598**, **5599**]. The quartz porphyry hereabouts, it should be noted, is very pyriteous; the country rock is a very compact amphibolite [**5594**]

with convolutions of a harder and coarser crystalline variety [5595]. The mine had a chequered career which appears to have been caused chiefly by bad financing. G.M.L.'s 831, etc., were surrendered in January, 1905, and then became part of the Valkyrie Consolidated, G.M.L. 936, which now exists.

The yield of the Valkyrie Reef is to be found in the table below:—

Table showing the Yield of the Valkyrie Reef.

Year.	Name and No. of Lease.	Ozs. dollied.	Tons crushed.	Tons cyanided.	Ozs. therefrom.	Ozs. from crushings.	Remarks.
1897 ...	St. Agnes Gold Reefs, 36, 480, 483	...	430·00	...	...	329·65	
1898 ...	St. Agnes Gold Reefs, 29, 35, 189, 483	...	1,080·00	...	...	593·80	
1899 ...	St. Agnes Gold Reefs, 29, 35, 189, 483, M.A. 7	...	324·00	...	...	217·62	
1899 ...	Valkyrie South, 778	...	124·00	...	...	137·00	
1900 ...	Do. ...	...	381·00	...	...	282·60	
1901 ...	Do. ...	...	38·00	...	...	6·90	
1901 ...	Valkyrie, 831 ...	...	52·00	...	...	80·27	
1902 ...	Do. ...	142·64	85·00	...	...	174·86	
1902 ...	Do. ...	...	...	47·75	8·37	...	State Battery
1903 ...	Do. ...	33·42	21·00	...	...	148·55	
1903 ...	Do. ...	...	...	30·00	6·73	...	State Battery
1904 ...	Valkyrie Leases, 83, etc.	...	621·00	...	...	819·85	=721 F.; 18·40 Silver
1904 ...	Do. ...	...	...	125·00	21·22	...	State Battery
1904 ...	Do. ...	107·15	...	...	...	...	= 93·71 F.
1904 ...	Unregd. Q.C., Fowler	...	6·00	...	..	7·59	= 6·38 F.; State Battery
1904 ...	Unregd. Q.C. 166, Waterloo	...	6·50	...	...	11·30	= 9·31 F.; State Battery
1904 ...	Do. ...	...	...	4·00	1·23	...	
		283·21	3,168·50	206·75	37·55	2,810·09	
						37·55	
						283·21	
						3,130·85	or ·988 ozs. per ton

Bonanza Reef.

Immediately to the south of the Valkyrie Consolidated is the Bonanza Reef which extends east and west for nearly 500 feet, underlaying south 40 degrees. It crosses the main quartz porphyry dyke from the Valkyrie mine; at this place it is from one to four feet thick, and has been tested to a depth of 60 feet. The quartz porphyry is very pyriteous. There are several other subsidiary reefs adjacent to this main reef. G.M.L's. 36 and 480, Valkyrie leases, became subsequently the Norseman South Bonanza, G.M.L. 731, which was forfeited in May, 1901; subsequently unregistered Q.C., held by Mr. Miller, was taken up, which gave place to the Bonanza, G.M.L. 829; this having been forfeited in April, 1902, eventually became the Bonanza, G.M.L. 859, and subsequently Taumutu G.M.L. 865. In 1903, Q.C. 121 was held by Mr. Fitz-

gerald for one month; but later on the Ajax, G.M.L. 882, was taken up. Altogether four shafts have been sunk on the reef, 45 feet, 40 feet, 30 feet, and 60 feet deep; at the latter the reef is stoped from the 60-feet level to the surface for 80 feet in length, it being richer here at the dyke crossing than elsewhere.

To the west of the above was the Great Norseman Junction G.M.L. 242, in the north-west corner of which Mr. Angove reported a vertical shaft of 50 feet; others have since been sunk in the south-west and south-east corners. It was abandoned in October, 1896. The south-east portion was subsequently the Klondyke, G.M.L. 693, which became void in October, 1898. On the east side of the last was the St. Agnes and Norseman Junction, G.M.L. 268, which was forfeited in August, 1896, and then re-numbered 742, and became void in August, 1900. To the east and south of these were two leases on which no work was done. The various details of the Bonanza Reef are given in the table below.

Table showing the Yield of the Bonanza Reef.

Year.	Name and No. of lease.	Ozs. dollied.	Tons crushed.	Tons cyanided.	Ozs. there-from.	Ozs. from crush-ings.	Remarks.
1898 ..	Klondyke, 693 ...	...	15·00	...	...	11·25	
1899 .	Norseman South Bonanza, 731	100·00	211·00	...	...	617·62	
1900 ..	Do. ...	...	...	...	...	...	
1901 ..	Do. ...	...	50·00	...	...	14·23	
1901 ..	Unregistered Q.C., Miller	...	15·00	...	...	4·54	State Battery
1901 ..	Bonanza, 829 ...	...	67·00	...	...	28·56	
1903 .	Q.C., 121 ...	...	7·00	...	...	10·54	
1903 ..	Ajax	...	...	4·00	2·18	...	do.
1903	Do., 882 ...	...	22·50	...	...	28·58	
1904 ...	Do., 882 ...	...	181·00	...	...	177·76	— 2·88 Silver 143·59 F. 3·90 F.
1904 ...	Do. ...	...	41·42	...	126·16	22·76	State Battery
		141·42	568·50	130·16	24·94	893·08 24·94 141·42	
						1059·44	or 1·863ozs. per ton

Note.—If the returns of the Valkryrie and Bonanza Reefs are taken together the yield is equal to 1·124ozs. per ton.

Mount Barker Reef.

Nearly half a mile eastward of the north end of the Norseman Reef is the Mount Barker Reef, which has a strike of about 80 degrees, and has been traced for a distance of $1\frac{1}{4}$ miles. It underlays to the east 60 degrees and more, and has been tested to 175 feet vertically below the surface. It has only yielded, however, 354ozs. of gold.

The north end of this reef was occupied by the Highfield, G.M.L. 121. Mr. Angove states that the shaft near the south end 90 feet, and another on west boundary 25 feet deep respectively.

The property subsequently became G.M.L. 527, under the same name, but was forfeited in September, 1897, and later on became in part the Mt. Barker No. 6 North, G.M.L. 668, from which there are no crushing returns. The reef outcrops in parallel lines on the west boundary, showing a strong body of stone. On the east side there is a very much crushed quartz-porphyry dyke [5612]. On the east side of the dyke there is an ironstone formation outcropping. There is a vertical shaft here 90 feet and an underlay 25 feet further north. This seems a locality worthy of more trial.

Next south is Mt. Barker No. 5 North, G.M.L. 109. There are three shafts here. Mr. Angove states that No. 1 shaft is 175 feet deep on easterly underlay on a reef which is four feet wide at the bottom. No. 2 is 70 feet and No. 3 30 feet deep on a reef three feet wide at the surface, but which has increased to seven feet at the bottom. The property subsequently became the Bulletin G.M.L. 846, from the reef in which a small crushing was obtained, particulars of which are to be found in the table.

Next south was the Mt. Barker No. 4 North, G.M.L. 107. The reef outcrops here near the centre of the lease, and there are three shafts upon it. Mr. Angove states that No. 1 shaft is 110 feet deep, and at 50 feet a drive goes 12 feet north on a lode (schistose formation) 12 feet wide; No. 2 shaft, on north part of lease, has been carried down 60 feet on a reef about two feet wide; No. 3 shaft is sunk 60 feet vertically. The lease was forfeited in September, 1897. Subsequently an unregistered Q.C., held by Mr. H. Parker, was taken up upon it, and Q.C. 133, Dead Finish, held by Mr. Fitzgerald and party, from which there have been several small crushings, particulars of which are to be found in the table.

On the west side was the Coromandel, G.M.L. 465, which subsequently became in part Q.C. 141, held by Woolford and party. Next south, was the Mt. Barker No. 3 North, G.M.L. 102. There seems to be two lines of lode here. The one on the west boundary has two vertical shafts of about 30 feet; the other lode has two shafts. One of these, Mr. Angove states, is 120 feet deep on an easterly underlay, the other, 100 feet deep, with drive 82 feet west to the other shaft, and also a drive on lode at the bottom; the lode formation, he says, is 12 feet wide. This lease belonged to the Norseman G.M. Co. in 1898, and there is no separate record of any crushing; it became void in November, 1898.

South of this was Mt. Barker Extended No. 2 North, G.M.L. 40, of 12 acres. Mr. Angove's account states that the main shaft was 90 feet vertical, and at 40 feet a crosscut west was 55 feet to main lode (this shaft, the writer understands, was subsequently deepened to 120 feet), and thence a drive along the lode 25 feet; another shaft was 80 feet on an easterly underlay (of 63 degrees) on the main lode with a drive 25 feet; another, 50 feet ditto on a parallel lode. Foul air was complained of in these workings. The formation here is schist with quartz and

ironstone, a sulphide lode evidently; the yield of this lode is shown in the table of returns. Q.C's. 145 and 146 were taken up hereabouts by Evans and party in September, 1903, and became void in November, 1898; subsequently the ground became in part NIL DESPERANDUM, G.M.L. 726, but was abandoned in June of 1899. South again was the MT. BARKER WELCOME No. 1 NORTH, G.M.L. 28. The lode is hidden by the surface material at the gully crossing, but appears strongly on the south side, where it is considerably contorted. Mr. Angove mentions that one shaft is 80 feet, another 82 feet deep, from which depth a crosscut has been driven 80 feet west. Having been voided in November, 1893, it subsequently became Q.Cs.' 104 and 107 and 109, held respectively by Messrs. Garrett and Nugent, and which were surrendered in April, 1903.

To the southward of this was the MT. BARKER, G.M.L. 14, taken up by Mr. R. G. Ramsay, 1894; this and the Reward Claim was worked by the Mt. Barker Reward G.M. Co. These two have two lines of reef; the main reef, 2 feet thick, already described northward, and another, the Agnes Venture Reef, that converges with a westerly underlay. The main shaft was sunk between them on the Reward Claim No. 2, and is down 200 feet. Mr. Catlin states that the first 100 feet is vertical, the rest on the lode, which underlies easterly. At the 100 feet level a drive goes 250 feet north, where it meets an underlay shaft, beyond this it continues 180 feet, where the reef pinches out; between the shafts it was 12 inches to 18 inches wide; from the 50-feet level in this underlay shaft there is a drive 35 feet north on a 12-inch reef and 50 feet south in broken country; from bottom of main shaft a drive goes 25 feet south on an 18-inch reef, where good gold was met with; water was first reached at 136 feet, and at 142 feet the flow was 1,000 gallons a day. No stoping has been done. Further north there is a shaft 65 feet on a very white quartz. The eastern reef was tried by a shaft for 50 feet but the stone gave out; 44 tons from here yielded 12ozs. of gold. There are two small shafts south of the main shaft on either the eastern reef or one parallel to it. There was a battery of ten stamps here jointly owned by this and the New No. 1 North Norseman Company, and there was also a cyanide plant. This lease became void towards the close of 1901, and was subsequently Q.Cs. 113 and 114, held by Messrs. Young and Nugent from August, 1902, to November, 1903; also Q.C. 169, by Mr. H. E. Delamotte for six months ending June, 1905. South of this was the MURRAY CHANNEL, G.M.L. 93, which, however, was abandoned in December, 1895, and subsequently became in part CORNSTALK EAST, G.M.L. 374. There is one shaft 60 feet deep. The Mount Barker Reef appears to terminate here near the crossing of the eastern reef, at least there is no sign of it on the valley flat. Eastward and adjacent to 374 was the LUCKY HILL, G.M.L. 369, near the eastern corner of which there is a shaft. Subsequent to the forfeiture of the lease in 1897 Q.C. 103, held by Howard and party, was taken up and held for nearly two years, although, however, the returns show only one small crushing from this locality.

The following table gives details of the yield of the Mount Barker Reef :—

Table showing the Yield of the Mount Barker Reef.

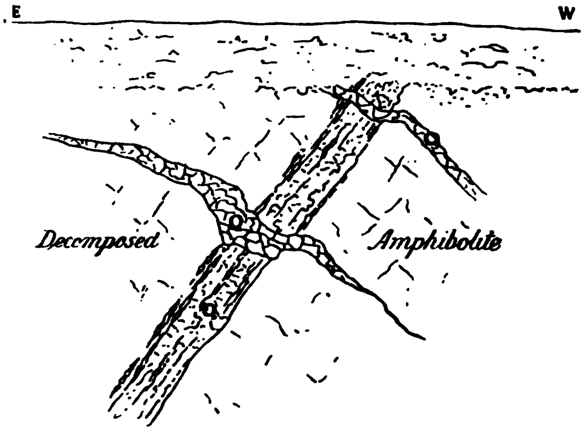
Year.	Name and No. of lease.	Dollied.	Tons crushed.	Tons cyanided.	Ozs. therefrom.	Ozs. from crushings.	Remarks.
1901 ...	Bulletin 846 ...	...	7·00	...	...	2·55	
1902 ...	Do. ...	...	7·00	...	...	3·58	
1902 ...	Unregistered Q.C. on 846	...	7·00	5·00	·89	3·58	State Battery
1897 ...	Mt. Barker No. 4 North 107	...	78·50	...	...	9·00	Bevilaqua
1902 ...	H. Parker on 107	...	11·50	...	...	4·16	State Battery
1902 ...	Q.C. 133, Dead Finish, on 107	...	16·00	...	...	5·60	Do.
1903 ...	Do. ...	...	10·00	8·00	2·21	4·80	Do.
1904 ...	Do. ...	...	7·00	4·00	·59	2·60	Do.
1903 ...	Q.C. 141 on 107 ...	...	10·00	...	...	2·64	Do.
1898 ...	Mt. Barker Extended No. 2 N. 40	...	58·00	...	...	10·80	
1898 ...	Do. ...	...	...	55·20	5·85	...	Do.
1899 ...	Do. ...	...	10·00	...	...	2·35	
1904 ...	Q.C. 145 N. on 140	...	50·00	...	...	27·25	= 23·21 F.
1902 ...	Q.C. 104 to 107, 109, on 28	...	150·00	92·50	24·18	92·12	State Battery
1903 ...	Unregistered Q.C., Richards	...	14·20	...	...	5·04	Do.
1903 ...	Unregistered Q.C., Hoffman	...	85·50	73·00	21·90	54·46	Do.
1904 ...	Unregistered Q.C., Jones	...	25·00	44·10	9·60	13·75	Do.
1897 ...	Mt. Barker Reward 14	...	136·00	...	...	26·10	
1898 ...	Do. ...	...	19·50	...	...	9·00	
1899 ...	Do. ...	...	...	...	...	...	
1900 ...	... ...	...	..	...	...	plates. 4·70	
1902 ...	Unregistered Q.C., Southwell, on 14	...	12·00		...	5·20	Do.
		...	714·20	281·80	65·22	289·28 65·22	
						354·50	or ·494 ozs. per ton
1902 ...	Q.C. 103 on 369 ?...	...	30·00	...	...	14·11	or ·470 ozs. per ton

Nellie May Reef.

About three-quarters of a mile east from the Record is the Nellie May, G.M.L. 873; here the decomposed rocks are within three feet of the surface, and a very rich patch of gold was found by an open cut on a line of quartz stringers which are intersected by cross veins making quite a network, the gold being found at the crossings of the veins. A shaft was being sunk at the time of my visit to test the ground at a greater depth. On the south-west side there are several outcrops of two parallel reefs trending north-east and south-west, underlaying southerly on which Q.C. 138, held by Campbell and

Smith from July, 1903, to January, 1904, was situated. A shaft was sunk on the reef, which proved very poor.

FIG. 14.



Q. INTERSECTING QUARTZ VEINS NELLIE MAY G.M.L. 873

The details of the crushings shown in the table below indicate that some very rich stone has been raised from this locality:—

Table showing the Yield of the Nellie May Reef.

Year.	Name and No. of lease.	Dollied.	Tons crushed.	Tons cyanided.	Ozs. therefrom.	Ozs. from crushings.	Remarks.
1903 ...	Nellie May, 873 ...	16·00	76·50	...	...	1392·05	
1903 ...	Do. ...	...	...	28·50	31·62	...	State Battery = 37·12 F.
1904 ...	Do. ...	...	24·50	...	...	40·51	
1904 ..	Do. ...	...	...	6·00	2·26	...	State Battery = 53·64 F.
1904 ...	Do. ...	58·56	...	...	...	...	
1905 ...	Q.C., 138 ...	...	34·00	...	...	6·10	
		74·56	135·00	34·50	33·88	1438·66	
						33·88	
						74·56	
						1547·10	or 11·460 ozs. per ton.

The Pot Luck Reef.

About a quarter of a mile south-west of the Nellie May, was the site of the POT LUCK NO. 1 NORTH, G.M.L. 291. A small north and south quartz vein occurs here: no work has been done, and the leases were declared void in November, 1896. South of this was the POT LUCK EXTENDED, G.M.L. 293, of 12 acres, on the same reef, but it was voided in November. 1896.

The Agnes Venture Reef.

The Agnes Venture Reef has a course slightly to the east of north, and has been traced from half-a-mile east of the north end of the Mt. Barker Reef. It crosses that reef at the Mount Barker Reward Claim and extends to the east side of the Valkyrie, a distance of three miles; it differs from the reefs hitherto described by underlaying to the west, and, besides the quartz, it is, to a considerable extent, accompanied by a graphitic schist and occassionally by a ferruginous formation. The reef has been tested to a vertical depth of 163 feet. This reef may perhaps indicate the westernmost appearance of the banded quartzite series that appear so extensively to the eastward.

The north end of this line was occupied by the Brocklesby, G.M.L. 375, where there was a ferruginous lode formatian, on which a shaft has been sunk, but no particulars of it are available; it is, however, probably about 30 feet deep. There are also two other quartz veins a few chains to the west. Adjoining the south boundary were the Ironsides, G.M.L. 294, of 12 acres, and the Pot Luck, G.M.L. 230, on a large outcrop of a very white quartz reef, where a 90-feet shaft has been put down on its underlay of 55 degrees; this latter property was voided in October, 1896. South of this was the Little Beatrice, G.M.L. 274 in which there is a shaft 60 feet vertical. This also was voided in October, 1896. South again was the Arcadia, G.M.L. 214, which appears to have been abandoned in April, 1896. Next was the Lady Alice, G.M.L. 238. Mr. Angove mentions that the shaft near the east boundary had been carried down 30 feet on the underlay of the reef, and that drive had been put in 12 feet to the west; also two shafts near the south-east corner, 35 feet, on the reef 12 inches wide. A quartz porphyry dyke occurs here with ironstone. On the west was the Josephine, G.M.L. 418. Mr. Angove states that one shaft near the north-east corner is 40 feet vertical, with a drive north 17 feet; another, on west boundary. 25 feet on a cross reef, with a drive east; whilst in the south-west corner another underlay shaft had been sunk 30 feet southerly.

South of 238 was the Surprise, G.M.L. 248, where there is one shaft of 25 feet. This was forfeited in September, 1896. On the west was the Lady Argyle, G.M.L. 367, upon which there are two shafts. Mr. Angove mentions one is 60 feet, with drive north and crosscut 30 feet west, and the other sunk on an easterly underlay of a reef which is 6 feet wide. This may be a re-appearance of the Lady Jean Reef.

To the south lay the Little Rachael, G.M.L. 136, which had a shaft 56 feet on west underlay and another 35 feet on a parallel lode, in addition to a third of 20 feet deep on a north-west and south-east reef. Having been forfeited in July, 1896, it subsequently became the Little Rachael, G.M.L. 528, which ceased to exist as such in January, 1897. South of this was the Union Jack, G.M.L. 166. The shaft in the gully, Mr. Angove states, was 90 feet

deep, cutting the reef at 80 feet. Another shaft of 30 feet was sunk on a cross reef. The Union Jack was forfeited in October, 1896, though it became subsequently the Union Jack, G.M.L. 588, but ceased to exist in February, 1899.

The reef next appears in the Mt. Barker lease, already described, and passes through the Reward Claim No. 2, crossing the Mt. Barker reef into the Cornstalk, G.M.L. 119. Mr. Angove states that the north shaft here is 40 feet deep and south shaft 90 feet deep. There is no information to hand as to whether any enrichment of the reefs occurred at their intersection. The Cornstalk ceased to exist in December, 1897.

Next south was the Great Boulder Norseman, G.M.L. 104. An ironstone formation occurs on the boundary between these two leases, underlying west, and a quartz reef on the west boundary, underlying east, on which there is a shaft; the rock adjacent to the reef is schistose. This reef will be described later as the Lady Jean Reef. The shaft on the east boundary, on a cross reef, Mr. Angove states, is 60 feet. A huge outcrop of very white quartz here is probably part of this Agnes Venture reef or lode. The Agnes Venture lode passes southwards from the Great Boulder into the Canny Scotchman, G.M.L. 198, where there are two shafts about 50 feet on its easterly underlay. Mr. Angove states that one was 60 feet, with a crosscut 55 feet west to the lode, and a drive 10 feet north on reef. This lease was forfeited in October, 1896; the lode then passes through the Blue Flag, G.M.L. 179. There is a shaft on it towards the south boundary, and a parallel formation about four chains to the eastward. Several shafts have been sunk here on two other reefs. Mr. Angove enumerates six shafts from 62 feet to 26 feet, with 46 feet drives. This formation is an outlying representative of the banded series which appears extensively half-a-mile eastward.

South of this is the True Blue, G.M.L. 233, which has a cross reef and small shaft on it. There is a vertical shaft near the south boundary on the lode, which Mr. Angove says is 40 feet deep, with a crosscut driven east.

South of this was the Agnes Venture North, G.M.L. 781; this and G.M.L. 782 were held by the Norseman, Limited, Syndicate, an English Company. There are two shafts here on the line of the lode, which underlays 60 degrees to west, it was voided in July, 1900.

Next south was the St. Agnes No. 2 North, G.M.L. 38; which subsequently became the St. Agnes No. 2 North, G.M.L. 142. Mr. Angove states that in August, 1896, there were three shafts, one vertical 51 feet, with drives south 22 feet and north 25 feet, and two underlay shafts 32 feet and 35 feet. The lease ceased to exist in November, 1899, but subsequently became Agnes

VENTURE, G.M.L. 782, which became void in July, 1902. The north shaft here is on a quartz reef underlying east; it intersects a quartz porphyry dyke; portions of both quartz and dyke show a banded character [**5945, 5949**]. The next shaft south, about 150 feet, shows graphite schist in the dump. A little farther south-west is Hart's adit on the CALEDONIAN, G.M.L. 885. It is 180 feet long, and was made with the idea of tapping the Valkyrie Reef on the underlay. It has since been abandoned, for it was found that the project was not a sound one. Two crushings have been obtained from this lease, details of which are to be found in the table of returns. About four to six chains southward of the adit there are two shafts on the lode line, where two cross reefs intersect it. The lode then cuts out, and re-appears about seven chains farther south, but about four chains to the east. This is in the KINGSWOOD, G.M.L. 123, upon which there are three shafts on the saddle of the cross ridge. Mr. Angove states that one is 195 feet on the westerly underlay and another 150 feet vertical and 60 feet on underlay, a crosscut connects the two shafts. Mr. Bevilaqua, who formerly held this lease, states that the latter had 50 feet driving, and that a third shaft is 100 feet; he said that a considerable amount of foul air occurred here. The lode is graphitic, with pyriteous quartz. The underlay is 75 degrees to west. The owner expected to be able to cut the St. Agnes Reef.

On the south-west side of the last was the ST. AGNES No. 1 NORTH, G.M.L. 46, which was eventually amalgamated with G.M.Ls. 142, 593. The property became void in November, 1899; subsequently it was known as the MOONLIGHT, G.M.L. 855, and finally as CALEDONIAN, G.M.L. 885, which was surrendered at the close of 1904.

Table showing the Yield of the Agnes Venture Reef.

Year.	Name and No. of lease.	Ozs. dollied.	Tons crushed.	Tons cyanided.	Ozs. therefrom.	Ozs. from crushings.	Remarks.
1896 ...	Kingswood 123 ...	...	10·00	...	...	15·00	Bevilaqua
1897 ...	Do. ...	...	10·00	...	..	5·50	Do.
1897 ...	St. Agnes No. 2 N 142	...	60·50	...	...	55·05	
1903 ...	Q.C. 115 on 142 ...	...	17·00	...	...	11·96	State Battery
1898	St. Agnes No. 1 N.E. 46	...	48·00	...	...	37·40	
1899 ...	Do. ...	...	45·00	...	...	12·00	
1902 ...	Moonlight 855 ...	...	14 00	...	...	5·65	
1903 ..	Q.C. Evans and party	...	38·00	75·00	·26	4·46	State Battery
1903 ...	Q.C. 115 on parts 113 and 782	...	17·00	...	...	11·97	Do.
			259·50	75·00	·26	158·99	
						·26	
						159·25 or	·614 ozs. per ton.

Lady Jean Reef.

The north end of this reef appears on the west side of the GREAT BOULDER NORSEMAN, G.M.L. 104, already mentioned at the middle of the line of the last reef, and to which it is nearly parallel, although it underlays to the east. The length of the reef is about 3,000 feet.

The main shaft of the Great Boulder is on this reef, and is probably 120 feet in vertical depth. The dump shows coarsely crystalline amphibolite and actinolite rock [5655]. This shaft was put down to intersect the Lady Jean Reef at a depth. A long line of quartz porphyry occurs in the west side of this main shaft. There are then two shafts 50 feet each on the same reef, which is from three to four feet wide, according to Mr. Angove, also an underlay shaft a few chains northward at an outcrop of the same reef.

South of this was the PEKIN, G.M.L. 118, on which there is a vertical shaft of 55 feet. The property ceased to exist in August, 1896, and was subsequently retaken up under the name of the PEKIN, G.M.L. 577, which, however, only was held until December, 1897.

South again was the CANTON, G.M.L. 92. There are two underlay shafts here on the Lady Jean Reef. Mr. Angove states that one is 52 feet, the other 60 feet in depth, and the reef nine inches to 12 inches wide. The lease subsequently became the CANTON, G.M.L. 244, from which a small crushing was obtained. Having been forfeited in 1896, it subsequently became the CANTON, G.M.L. 576, and, in 1897, in part LADY JEAN NORTH, G.M.L. 800.

South of this was the MIDDLETON, G.M.L. 91, owned by G. T. Sinclair, who is stated to have expended £800 on the lease; shafts, one 110 feet deep with 60 feet drives; one 55 feet, and three others 25 feet to 30 feet have been sunk. The Middleton was voided in 1897, and subsequently became the LADY JEAN, G.M.L. 757. These three last leases were amalgamated in July, 1900. The old shaft at the south-west corner is 45 feet vertical, and continued for a further distance of 125 feet on an underlay of 25 degrees. There are drives at 60 feet and 150 feet respectively. At 110 feet the oxidized zone begins to change to harder rock, and at bottom the rock is a slightly schistose amphibolite. At the south end of the lower drive the country rock becomes considerably ferruginous. A new shaft towards the centre of the lease is vertical 70 feet, all in soft brown oxidized rock. The reef averages 12 inches. Cross courses of quartz about 1 inch to 2 inches in thickness are met with in both workings; they occurred at a rich patch, but cannot be said to indicate gold. In addition, slickensided faces are numerous, indicating horizontal movement [5952], along the plane of the reef. There is also a shaft 50 feet and two shafts 30 feet each. Up to May, 1905, between £4,000 and £5,000 had been expended on the mine.

South-west of 757 was the MILDURA BLOCK EXTENDED, G.M.L. 235, this, having been surrendered, subsequently became Q.C. 110, which existed as such from July, 1902, to January, 1904.

On the east side of this was the NORSEMAN CENTRAL, G.M.L. 267. There is a shaft sunk here down to the Lady Jean Reef, which continues south into these last two leases.

The various details connected with the gold yield of the Lady Jean Reef will be found in the table below:—

Table showing the Yield of the Lady Jean Reef.

Year.	Name and No. of lease.	Ozs. dollied.	Tons. crushed.	Tons cyanided.	Ozs. therefrom.	Ozs. from crushings.	Remarks.
1899 ...	Canton, 244 ...	...	6·00	...	...	2·70	
1900 ...	Canton, with 757, *see* below	...	...	...	...	...	
1901 ...	Q.C., Hoffman, Canton	...	6·00	...	...	2·54	State Battery
1902 ...	Do. ...	...	...	4·00	·63	...	Do.
1903 ...	Unregd. Q.C., Evans, 244	...	16·00	12·50	5·71	4·51	Do.
1898 ...	Middleton, 91 ...	...	23·00	...	...	3·75	
1899 ...	Do. ...	...	7·00	...	...	1·35	
1899 ...	Lady Jean, 757 ...	6·00	82·00	...	...	202·17	
1900 ...	Do. ...	...	293·00	...	...	373·93	
1900 ...	Do. ...	...	...	43·50	4·93	...	State Battery
1901 ..	Lady Jean, 757, 800	...	381·00	...	...	508·54	
1901 ...	Do. ...	...	...	275·00	68·10	...	State Battery
1902 ...	Do. ...	...	335·00	...	...	715·97	
1902 ..	Do. ...	...	...	201·50	61·45	...	State Battery
1903 ...	Do. ...	...	260·00	...	...	409·15	
1903 ...	Do. ...	...	...	191·50	44·32	...	State Battery
1904 ...	Do. ...	...	189·00	...	..	280·88	=244·44 F. 17·66 Silver
1904 ...	Do. ...	...	...	210·91	59·93	...	State Battery
1904 ...	Q.C., 110 on 235 ...	.	31·00	...	...	11·20	
		6·00	1,629·00	938·91	245·01	2,516·69 245·07 6·00	
						2,767·76 or 1·695 ozs. per ton	

The Lone Hand Reef.

Adjacent to the south boundary of the Norseman townsite there are several cross reefs and north and south reefs on which six leases were taken up, but very little is known now concerning the workings. THE SPIRIT OF THE WEST, G.M.L. 264, had a cross reef, underlying south, on which two shafts have been sunk 50 feet and 60 feet. On the east side of this was the LONE HAND, G.M.L. 141. Mr. Angove enumerates five shafts, two 90 feet on westerly underlay on two parallel lodes; one was on a reef 4 feet 6 inches wide, driven on south 30 feet; in the other at 70 feet level there is a drive south 40 feet on a reef 5 feet wide. Another shaft vertical 40 feet, another 40 feet on a reef 2 feet wide, another 40 feet (*see* returns). To the south of this was the JOKER, G.M.L. 148, on which three

shafts have been sunk, but no particulars are obtainable regarding them.

Table showing the Yield of the Lone Hand Reef.

Year.	Name and No. of lease.	Ore crushed.	Yield.
		tons.	ozs.
1897 ...	Lone Hand, 141	**150·00**	**16·50**
		or ·11ozs. per ton	

The Star of Erin Reef, etc.

About half a-mile south-easterly from here some quartz porphyry dykes occur, these have been followed by short quartz reefs. Here was the Midas, G.M.L. 135, which was held by the Midas G.M. Co., which gave, however, most attention to their other lease the John Bull. Mr. Angove states that Brown's shaft was 65 feet deep (on the Midas reef) underlying south; another 70 feet deep also underlying south, with a drive east for 20 feet on same, with a fair amount of stoping. There is also a smaller north and south reef on the eastern side [5997]. Between two of the quartz porphyries occurs an intrusive diorite dyke [5995]. The amphibolite forming the country rock has been altered near to it into mica schist [5996]. This lease became void in October, 1898, and was subsequently in part Q.C. 30, held by Geo. Graham for a period of four months in 1899, when it became G.G., G.M.L. 743. This latter became void in August, 1900, and was subsequently Q.C. 79, held by the same party until January, 1901; part also of G.G. became Q.C. 80, and was held until January, 1904, about when it became Star of Erin, G.M.L. 905. This having been forfeited in July, 1905, was applied for again as Star of Erin, G.M.L. 946.

The yield of the Star of Erin Reef is given in detail in the table below:—

Table showing the Yield of the Star of Erin Reef.

Year.	Name and No. of lease.	Dollied.	Tons crushed.	Tons cyanided.	Ozs. therefrom.	Ozs. from crushings.	Remarks.
1899 ...	Q.C. 30	...	18·00	...	...	13·18	Bevilaqua
1899 ...	G.G., 743	·75	60·00	...	...	20·65	
1900 ...	Do.	...	50·00	...	...	30·90	State Battery
1901 ...	Q.C. 79	...	19·00	...	...	8·03	Do.
1902 ...	Q.C. 80	...	...	30·00	8·03	...	Do.
1903 ...	Do.	...		...	...		
1904 ..	Star of Erin, 905	...	30·50	...	...	13·02	= 11·27 F.
1904 ..	Do.	12·83	...	...	...	...	= 10·83 F.
		13·53	**177·50**	**30·00**	**8·03**	85·78	
						8·03	
						13·53	
						107·34 or ·605ozs. per ton.	

The O.K. Reef.

About 15 chains south of the G.G. is the O.K., G.M.L. 903, where there is a shaft 85 feet on the underlay on east and west reef, which dips at 80 degrees south. The reef ranges up to 3 feet in thickness, though the average is about 12 inches. It is a ferruginous quartz, showing gold in places [5998]. To the east and west are the O.K. EAST and O.K. EXTENDED, lately taken up. Half-a-mile south is the commencement of the Mt. Benson group of reefs, which are mostly short, but have proved good producers of gold. They radiate to the north-east, east, south-east, and south-west from the west corner of G.M.L. 43, MT. BENSON as an approximate centre. The northernmost lease on this ground is the ST. VINCENT, G.M.L. 208, which was forfeited in November, 1896.

On its south-east side was the MT. BENSON NORTH, G.M.L. 535, where there is a small north-east and south-west reef, with a shaft on the underlay southerly. The reef skirts the west side of a small quartz porphyry dyke. Having been abandoned in April, 1897, both these leases subsequently became in part MT. BENSON NORTH, G.M.L. 616, and later Q.C. 39, held by W. E. Evans till January, 1904.

The various crushings on the O.K. REEF showed its average to be about 1oz. per ton. The details are to be found in the table below:—

Table showing the yield of the O.K. Reef.

Year.	Name and No. of lease.	Dollied.	Tons crushed.	Tons cyanided.	Ozs. therefrom.	Ozs. from crushings.	Remarks.
1904 ...	O.K. 903	...	221·00	...	...	215·47	189·61 F
	Do.	...	...	150·66	42·85	...	State Battery
1904 ...	Unregistered Q C., R Peake	...	6·50	...	...	2·15	= 1·77 F
1896 ...	Mt. Benson N., 535	...	19·50	...	...	21·75	Bevilaqua
1897 ...	Do.	...	...	...	...	...	
1898 ...	Do.	...	15·50	...	...	8·20	State Battery
1899 ...	Q.C. 39	...	...	...	...	...	
		...	262·50	150·66	42·85	247·57 42·85	
						290·42	or 1·104 ozs. per ton.

The Oversight Reef.

South of the Q.C. 39 was the NORTH BENSON, G.M.L. 62, which subsequently became the MT. BENSON No. 1 NORTH, G.M.L. 565, having been forfeited in September, 1898. A quartz claim, Q.C. 9, held by Geo. Graham, was taken up and a small crushing put through, as may be seen in the return, subsequently this became

in part the OVERSIGHT, G.M.L. 914. A vertical shaft has been sunk 93 feet near the middle of the lease on what is apparently the continuation of the Discovery Reef. The reef is much intermixed with the amphibolite country rock, so much so that pyritous amphibolite in parts alone represents the reef, but this has been crushed with the quartz, as it carries fair gold.

Table showing the Yield of the Oversight Reef.

Year.	Name and No. of lease.	Ore.		From cyanide.	From ore.
		Crushed.	Cyanided.		
		tons.	tons.	ozs.	ozs.
1898 ...	Q.C. 9 (Graham) on 565 ...	15·50	...	...	8·23
1904 ...	Oversight, 914	28·00	...	...	74·95 (or 66·71F)
		...	14·00	12·45	...
		43·50	14·00	12·45	83·18
					12·45
					95·63 or 2·198ozs. per ton

The Cumberland Reef.

Ten chains south-east of the Oversight was the east end of Hall's Reef, on which was situated the JOHN BULL, G.M.L. 53, held by the Midas G.M. Co. There were in June, 1900, five shafts, 140 feet, 100 feet, 85 feet, 60 feet, and 50 feet deep respectively, with 500 feet of driving and 100 fathoms of stoping. The lease was amalgamated with the Mt. Benson G.M. Co. in April of 1903.

On the west of the John Bull was the Mt. Benson G.M. Co.'s leases, MT. BENSON, G.M.L., 43 occupying the west end of Johnson's Reef and the John Bull Reef, which joins it. The MT. BENSON EXTENDED, G.M.L. 42, which has the western portion of Hall's Reef and the Discovery Reef and the MT. BENSON WEST, G.M.L. 816, these were amalgamated in the early part of 1901. The Mt. Benson West became subsequently the Evening Star, G.M.L. 889. The Company stated in February, 1902, that in G.M.L. 43 they had sunk six shafts, 140 feet, 115 feet, 85 feet, two 60 feet, 50 feet deep respectively, with 923 feet drives and 81 feet crosscuts; in G.M.L. 42, six shafts, of 120 feet, 110 feet, 100 feet, 350 feet respectively, with 751 feet driving and 30 feet crosscuts. In lease 816, five shafts, two 60 feet

deep, one 50 feet deep, and two 30 feet deep. In lease 53, five shafts, 205 feet, 120 feet, 90 feet, 25 feet, 20 feet deep, with 167 feet drives, and 111 feet crosscuts. In March, 1903, this Company was amalgamated with the Cumberland G.M. Co. whose properties adjoined them on the south side, holding G.M.Ls. 579, 690, in which was the Cumberland main reef and G.M.L. 700. The last one was, however, abandoned. The Company's ground then comprised G.M.Ls. 42, 43, 898, 889, and 53, having a total of a little over 86 acres. The Cumberland Co. stated in December, 1902, they had crushed 4,398 tons of stone yielding 4,230 ozs., which at the average value per oz. for that year of £3 11s. 6¼d. equals £15,126 (Fig. 15). The work done at the time of amalgamation in G.M.L. 681 comprised two shafts 80 feet and one 30 feet deep, with 167 feet of driving in addition to 111 feet crosscuts. In G.M.L. 816 there were two shafts 60 feet, one 50 feet, and two 30 feet deep with 55 feet driving.

In the present Cumberland Gold Mine only one reef, Hall's Reef, was being worked at the time of my inspection, viz., that in G.M.L. 42, Mt. Benson Extended. It has approximately an east-north-east course underlying 70 degrees to south. The new main shaft is here 350 feet vertical depth, with levels at 150 feet, 250 feet and 350 feet; very little stoping has as yet been done.

The lower level had been driven 167 feet east [5981] and 137 feet west [5982]; the upper was 332 feet east [5983] and 148 feet west. It has since then been connected with the Monday shaft workings for ventilation purposes. The reef has an average width of about two feet six inches in the upper levels. The walls are very well defined and regular; the quartz has a bluish colour and frequently has numerous inclusions of a formation or gossan. The gold is very fine and the ore is free milling. The old workings on this reef are to the eastward and comprise two underlay shafts and a drive at about 60 feet. About 50 feet from the easterly boundary another reef, the John Bull, meets this reef in a south-south-east direction underlaying 75 degrees to the north and they unite. The John Bull Reef has been driven on for a short distance to the west and also eastward to the 80 feet vertical shaft at the quartz porphyry dyke. This shaft is known as the John Bull or Bickford shaft. The reef is about 18 inches in thickness average, but narrows greatly on passing into the dyke which underlays 60 degrees to west.

In the next lease south of this is Johnson's Reef, it has a more south-easterly course and extends into the Avon, G.M.L. 898. The reef has a southerly underlay of about 70 degrees and has been worked from the western end by an adit 420 feet long with underlay shafts; it probably averages two feet wide. The formation is larger than in Hall's reef. In the upper portion this is represented by a

Photo., W. D. CAMPBELL. Govt. Photo. Litho.

Cumberland, G.M.L. 42. Mt. Benson North, looking south-east.

clay in which the then manager states that "slugs" of gold were embedded; it is stoped from the adit level to the surface.

The eastern continuation of Johnson's reef was in the MT. BENSON No. 1 EXTENDED, G.M.L. 52. In April, 1899, this lease was merged into the Kirkpatrick Mt. Benson G.M. Company, which, then, also held the RISING SUN, G.M.L. 71, and the KIRKPATRICK MT. BENSON, G.M.L. 614. In November, 1901, the Company stated that in lease 82 they had sunk five shafts, two of 140 feet, 120 feet, 60 feet, and 30 feet, and also 670 feet of drives and 222 square yards of stoping. I was informed that the main shaft towards the eastern end of 52 lease is 160 feet vertical depth. Lease 52 became void in July, 1903; the northern portion became the AVON, G.M.L. 898, and is held by the Cumberland G.M. Company.

Monday shaft is on the southerly sweep of Hall's reef. The reef is here very variable, averaging about nine inches wide, but is rich in places; on the south side of the shaft it bifurcates. The eastern branch is highly pyriteous. The quartz porphyry dyke adjacent to the shaft is also highly pyriteous and underlays to the west; it was apparently met with in the Cumberland West shaft at 90 feet, thus showing an underlay of about 32 degrees.

The DISCOVERY REEF is about seven chains north of Hall's reef. There is here a vertical shaft about 100 feet with drives east and west on an 18 inch reef at bottom, which carries fair values. This reef is evidently identical with that in the Oversight lease already referred to.

The CUMBERLAND MAIN REEF trends north-east and south-west across the western summit of the hill in G.M.L. 579, the CUMBERLAND; it underlays 70 to 80 degrees to the west and outcrops on the west side of a quartz porphyry dyke having the same direction. A special feature of this reef is the occurrence of cross spurs of quartz; these are curved about greatly. A schistose formation or gossan occurs on either side of the reef carrying calcite and pyrites ([**5978**] assays 10 grains per ton). The chutes of ore dip south, and the reef makes and pinches greatly from 6 inches to 6 feet in thickness.

The reef has been traced across the Southern lease 690, the WAIPUKERAU, which was previously in part the NEW ZEALAND, G.M.L. 58, where Mr. Angove states it was 1 foot 6 inches to 3 feet thick, carrying good values. The main shaft is vertical, about 15 chains south of the Monday shaft, and is 227 feet deep, with levels at 73 feet, 185 feet, and 217 feet respectively, and an adit level. Considerable sized bunches of iridescent iron pyrites occur in the lowest level, and are said to carry gold in places [**5977**]. The workings of this mine are shown on Plate III.

There are also workings on the ends of the east and west Kirkpatrick reefs, which extend easterly into this lease.

The following table gives the yield of the group of reefs described above:—

Table showing the Yield of the Cumberland Reefs.

Year.	Name and No. of lease.	Dollied.	Tons crushed.	Tons cyanided.	Ozs. therefrom.	Ozs. from crushings.	Remarks.
1896 ...	Cumberland G.M., 579	...	160·00	...	...	216·00	
1897 ...	Do. ...	...	210·00	...	...	157·58	
1898 ...	Cumberland G.M., 579, 690	...	420·10	...	...	1,520·50	
1899 ..	Cumberland G.M., 579, 690, 700	...	568·00	...	...	524·73	
1900 ...	Do. ...						
1901 ...	Do. ...	...	1,004·00	...	...	1,053·15	
1902 ...	Do. ...	...	733·00	...	...	687·96	
1903 ...	Cumberland G.M., 42, 43, 53, 579, 690	...	·05	1,100·00	580·48	3·83	
1904 ...	Cumberland G.M., 42, 43, 53, 379, 690, 889, 898	...	4,324·00	...	...	6,356·42	=5,724·46 F.
			7,419·15	1,100·00	580·48	10,520·17 580·48	
						11,100·65	or 1·496ozs. per ton.
1896 ...	Mt. Benson G.M., 42, 43	...	1·50	...	...	19·00	
1897 ...	Do. ...	...	610·90	...	...	527·17	
1898 ...	Mt. Benson G.M., 42, 43, 681	...	1,867·00	...	...	1,459·30	
1899 ...	Do. ...	...	972·00	...	...	1,362·70	
1900 ...	Do. ...	...	930·00	...	...	914·56	
1901 ...	Do. ...	...	132·00	...	...	252·80	
1902 ...	Do. ...	...	184·00	...	...	187·05	
			4,697·40	...	...	4,722·58	or 1·0067ozs. per ton.
1898 ...	John Bull Midas G.M. Co., 53	...	314·00	...	...	315·15	
1899 ...	Do. ...	...	366·00	...	...	206·24	
1900 ...	Do. ...	...	50·00	...	...	30·90	
			730·00	...	...	552·29	or ·7565ozs. per ton.

The Excelsior and Eureka Reefs.

The Eureka, G.M.L. 728, south of the Mt. Benson North, has two shafts near its eastern boundary upon what may be a continuation of the Discovery reef.

South of the Eureka was the Mt. Benson West, G.M.L. 259. This lease occupied portion of the same ground as G.M.L. 816 of the same name already referred to among the Mt. Benson G.M. Co.'s leases. Mr. Angove mentions three shafts, one 45 feet on the underlay of the reef, with a drive south 8 feet; another shaft 40 feet, vertical; and a third 35ft., in progress in 1896.

South of this was the CUMBERLAND WEST, G.M.L. 897, on existing lease, and CUMBERLAND WEST EXTENDED, G.M.L. 927, which are both situated on the west side of G.M.L. 579. In the former there is a shaft on the underlay east of a reef, which is parallel to the Cumberland main reef. Mr. Angove states that this is 40 feet deep, and the reef 4 feet wide, carrying gold at surface. This ground was then EXCELSORA MAGNA, G.M.L. 275, where Mr. Angove states there was a shaft 40 feet on the underlay of a 4 feet reef, carrying gold from surface. A new shaft is being sunk at the eastern end to endeavour to find the Cumberland reef on the west side of the quartz porphyry dyke at the west end of that reef. The lease also includes a shaft on its south boundary. This was probably the one Mr. Angove mentions in the then ALICE, G.M.L. 354, as being 30 feet vertical, with a crosscut 40 feet west, but no reef was found. The dump shows fine grained pyritous amphibolite [5094].

The yield from these two reefs as shown in the table below is small.

Table showing the Yield of the Excelsior and Eureka Reefs.

Year.	Name and No. of lease.	Tons treated.	Tons cyanided.	Ozs. from cyanide.	Ozs. therefrom.	—
Previous to 1897	Excelsora Magna, 275	20·00	...	...	4·00	
1902 ...	Eureka, 728 ...	10·00	9·00	1·08	2·53	State battery
		30·00	**9·00**	**1·08**	6·53	
					1·08	
					7·61	or ·**254** oz. per ton

The Recoupe Reefs.

On the south side of the Cumberland Company's ground were the RECOUPE REEFS. These are two or more short reefs underlaying south and approximately parallel with the Kirkpatrick reefs, which will be described next. The THREE STARS, G.M.L. 220, was here. The main shaft was in the northern, the principal reef. The lease was forfeited in March, 1897. It was in part subsequently the RECOUPE, G.M.L. 681, from which two small crushings have been recorded. The Recoupe was surrendered in April, 1904. It eventually became the RECOVERY, G.M.L. 913, from which another small crushing was recorded in 1904.

One of the Recoupe reefs runs into the next lease west, the ATHELSTONE, G.M.L. 325. There is a shaft on it, probably the 30-foot shaft mentioned by Mr. Angove, on a reef one foot wide at surface, but which cut out at the bottom of the shaft. Another shaft about 150 feet north-west appears to be on the main reef. It

had been carried down 57 feet on the underlay. There was also a drive north on reef, and a crosscut 55 feet. The material in the dump shows a little copper ore. At the south end of this lease there is another parallel reef with a shaft upon it. It goes into the next lease eastward, the Hope, G.M.L. 252, where, according to Mr. Angove's account, there are three shafts. No. 1 is 39 feet on small leaders. No. 2 is 40 feet on reef 20 inches wide. No. 3 is 30 feet on easterly underlay, with a drive on the bottom on reef one foot wide. There are no crushing returns from these leases. On the east side of the Hope was the Auraria, G.M.L. 357. Mr. Angove mentions two reefs, one 18 inches, of poor quality, and one 2 feet 6 inches on which there were two underlay shafts 41 feet and 40 feet. There appears to have been no work done since, and there do not appear to have been any crushing returns.

The table attached gives the yield of the Recoupe Reefs:—

Table showing the Yield of the Recoupe Reefs.

Year.	Name and No. of lease.	Ozs. dollied.	Tons crushed.	Tons cyanided.	Ozs. therefrom.	Ozs. from crushings.	Remarks.
Previous to 1897	Three Stars, Mt. Benson, No. 2 Extended, 220, 257	...	20·00	...	...	24·00	
1897 ...	Do.	...	36·00	...	...	14·00	Bevilaqua.
1897 ...	Recoupe, 681	...	30·00	...	...	16·50	
1898 ...	Do.	...	70·00	...	...	33·55	
Note.—1899 to 1902, *see* 42 and 43.							
1903 ...	Recoupe, 681	...	150·00	...	...	323·95	
1904 ...	Do.	...	...	69·00	36·08	...	State Battery =6·30 F.
1904 ...	Do.	8·23	...	...	...	...	
1904 ...	Unregistered Q.C., Rogers	...	19·00	...	...	13·80	State Battery
1904 ...	Do.	...	...	15·49	32·08	...	State battery. 24·23 F.
1904 ...	Recovery, 913	31·68	...	...	...	...	
		39·91	325·00	84·49	68·16	425·80 68·16 39·91	
						533·87 or 1·643 ozs. per ton.	

The Kirkpatrick Reefs.

The Kirkpatrick Reefs are two east and west reefs on the east side of the Cumberland G.M. They are each about 800 feet in length, and underlay south about 35 degrees, and, moreover, have been tested to a depth of about 130 feet. They are small, but have rich pockets of ore. Slickensides are frequent in the walls of the reefs, whilst the quartz is more ferruginous than usual in the district. The reefs were occupied by the Rising Sun, G.M.L. 71, and the Kirkpatrick Mt. Benson, G.M.L. 614. On lease 71, the Company stated that in 1901 there were four shafts, 160 feet, 134 feet, 60 feet, and 30 feet deep respectively, and 641 feet of drives, in addition to 3,982 sq. yards stoping, and had crushed 895 tons of

stone for 988ozs. A double row of quartz porphyry dykes traverses these leases in a north-easterly direction; the eastern one is either accompanied by a porphyry vein or it changes into [5985] porphyry similar to that occurring in the Norseman No. 1 North. The vertical shaft at the north-east corner of G.M.L. 71 is 168 feet deep. The crosscuts east and west at the bottom show one quartz porphyry dyke to west of the shaft, and two on the eastern side. These dykes are pyritous, and also slightly auriferous [5986, 5987, 6120, 6121].

These leases became void in July, 1903, and became in part Q.C. 147, and held by Messrs. Graham and Marquand from September, 1903, to October, 1904; Q.C. held by Baker and Wooding from September, 1903, to October, 1904; Q.C. 165, TIPPERARY, held by D. E. Smith from June, 1904; and Q.C. 167, held by Messrs. Graham and Marquand, from October, 1904.

The central portion is now embraced by the CUMBERLAND EAST, G.M.L. 896, and also UNREG. Q.C., held by Wooding and party in Decembor, 1904.

The details connected with the various crushings on the Kirkpatrick Reefs are given in tabular form in the return appended:—

Table showing the Yield of the Kirkpatrick Reefs.

Year.	Name and No. of lease.	Ozs. dollied.	Tons crushed.	Tons cyanided.	Ozs. therefrom.	Ozs. from crushings.	Remarks.
1896 ...	Kirkpatrick Mt. Benson, 614	...	100·00	...	...	88·90	Bevilaqua
1898 ...	Do., 52, 71 ...	...	200·00	...	...	297·29	
1899 ...	Kirkpatrick Consolidated, 52, 71, 614	...	296·00	...	...	329·63	
1900 ...	Do.	...	316·50	...	...	282·97	
1901 ...	Do.	...	144·50	...	...	115·53	
1901 ...	Do.	...	...	88·00	23·81	...	State Battery
1902 ...	Do., 52, 71 ...	...	182·00	...	...	139·91	
1902 ...	Do.	...	...	9·00	2·34	...	State Battery
1902 ...	Kirkpatrick Mt. Benson G.M. 614	...	76·00	...	...	29·32	
1902 ...	Rising Sun, 71 ...	13·25	28·50	...	...	124·20	
1903 ...	Do.	31·00	13·00	...	...	12·34	
1904 ...	Q.C. Wooding, 71	...	27·00	...	...	32·60	29·03 State B.
1903 ...	Quartz Claims 147, 153, 165, 167	...	131·50	62·50	19·84	116·46	State Battery
1904 ...	Cumberland East, 896	...	101·00	...	...	111·04	= 100·17 F.
1904 ...	Do., 896 ...	7·53	...	...	...	...	= 5·80 F.
		51·83	1,616·00	159·50	45·99	1,680·19	
						45·99	
						51·83	
						1,778·01	or 1·100ozs. per ton

The Try Again Reef.

On the east side of the Kirkpatrick Mt. Benson was the TRY AGAIN, G.M.L. 159, the reef in which may be a continuation of the Johnson's reef. Mr. Angove mentions three shafts, 60 feet deep,

40 feet and 25 feet on the underlay, the first two are connected at 30-feet level. The width of the reef varies from 15 inches to 2 feet. A small crushing from here yielded ½oz. to the ton, and is included in the returns from the Union Reef.

The Union Reefs.

The Union Reefs are parallel reefs, three and perhaps four in number, having a steep underlay to the north similarly to the John Bull reef, of which they are probably a continuation. The reefs are mostly one foot wide and carry good values, with formation on the walls; they trend south-east. THE UNION, G.M.L. 114, was held by an Adelaide Company. The main shaft is on the footwall side of the main reef, vertical, and carried down to a depth of 129 feet. Mr. Catlin states that at 30-feet level drives go 70 feet north-west and 55 feet south-east, with some stoping; at 75 feet level drives go 50 feet north-west and 20 feet south-east, also a crosscut north-east for 125 feet, communicating with the workings on the next reef, where the principal shaft is 80 feet deep, with drives at 30-feet level, 60 feet west and 50 feet east; also at 70-feet level drives go east 50 feet and west 45 feet. Another shaft 150 feet further west is 70 feet, the bottom being in quartz. The lease became void in October, 1899, and was subsequently in part the UNION JACK, G.M.L. 812, which was voided in July, 1903; it subsequently became in part EARLY DAWN, G.M.L. 888, and having been surrendered in February, 1904, it eventually in part CUMBERLAND EXTENDED, G.M.L. 925. It is now CUMBERLAND EXTENDED, G.M.L. 934. There was also here Q.C. 56, held by A. E. Pike for five months in 1900, and Q.C. 64, held by H. Pike from September, 1900, to January, 1904. The few crushings from the Union Reef are recorded below.

Table showing the Yield of the Union Reefs.

Year.	Name and No. of lease.	Ozs. dollied.	Tons crushed.	Tons cyanided.	Oz. therefrom.	Oz. from crushings.	Remarks.
1896 ...	Try Again 159 ...	...	31·90	...	...	17·00	Bevilaqua.
1897 ...	Union 114... ...	...	289·00	...	...	207·45	
1898 ..	Do.	...	196·00	...	..	50·35	
1899 ...	Do.	...	334·00	...	...	152·80	
1900 ...	Union Jack 812 ...	...	89·00	...	...	120·97	
1901 ...	Do.	...	276·00	...	...	312·17	
1902 ...	Do.	...	128·00	...	...	114·46	
			1343·90	...	...	975·20	or ·725 ozs. per ton.

The Kadince Reef.

On the east side of the Union was the KADINCE, G.M.L. 202, in which there are three or four small east and west reefs underlying south from 70 to 80 degrees. The southernmost one is quartz and ironstone. Mr. Angove states that three shafts here were 40 feet

such; the stone is said to yield fair values. The lease was void in December, 1897, but some recent work has been done there, but there do not appear to have been any returns therefrom.

The Wilgena Reef.

Half a-mile due south from CUMBERLAND EAST, G.M.L. 896, there are two reefs on the north foot of the Woolyenyer ridge, strike north-east, underlay south 70 degrees, on which there are three shafts. The width of quartz is about 18 inches, and has a good appearance. This is probably the site of Q.C. WILGENA, from which there was a crushing at the State Battery.

Table showing the Yield of the Wilgena Reef.

Year.	Name and No. of lease.	Ore treated.	Gold therefrom.	Remarks.
		tons.	ozs.	
1897 ...	Q.C. Wilgena	20·00	4·00	State Battery
1898 ...	Do.	6·00	1·30	Do.
	Total	**26·00**	**5·30**	or ·204ozs. per ton

The Lucky Shot Reef.

One mile south-westerly from the Cumberland G.M., on the north spur of Mt. Woolyenyer, near a quartz porphyry dyke, there is a large outcrop of white quartz, trending north-east and south-west, underlaying 55 degrees north-west, on which there was a shaft and open cut. This was the site of the LUCKY SHOT, G.M.L. 407. There are two small prospecting shafts about eight chains south-easterly from the other one.

The Virginia Reef.

On the south side was the VIRGINIA, G.M.L. 520, of 12 acres, where there is an east and west reef underlaying south about 70 degrees, on which there are two shafts. Q.C. 10 was here subsequently held by James Birrell; was abandoned in January, 1899.

Table showing the Yield of Virginia Reef.

Year.	Name of lease.	Ore treated.	Gold therefrom.	Remarks.
		tons.	ozs.	
1898 ...	Q.C., 10	**8·00**	**3·94**	or ·496ozs. per ton State Battery

The Norse Queen Reef.

Half a mile south-west from here was the NORSE QUEEN, G.M.L. 303, at the 122-Mile Peg on the Esperance to Coolgardie

Road. There is here a north and south reef about three feet wide; only a small trench has been made on it.

The Norseman Empress Reef.

On the east side was the Norseman Empress, G.M.L. 452, in which there is a reef outcropping on the south side of a quartz porphyry dyke. The reef trends north-east and south-west and underlays 75 degrees southerly.

The Mount Kirk Reef.

Southward of this the amphibolite country rock and all the outcrops are hidden by surface accumulations on the flat that extends westerly for a mile and a half to the blown sand ridges bordering the west side of Lake Kirk. The edge of the lake around a small hill there on the telegraph line shows a flat rocky floor which can be seen to be seamed by numerous quartz veins all trending in a north-easterly and south-westerly direction. A few also occur on the similar rocky floor on the west side of the lake with the same direction, but the bulk of the quartz in this part follows four lines of ferruginous and sulphide lodes that appear with banded quartzites, having a bearing slightly west of north. These all underlie to the west from 45 to 75 degrees. The quartz reefs range occasionally up to about 2 feet 6 inches wide and are slightly ferruginous. The quartzites are a few feet wide only on the first three lines, as far westerly as the Italia, but the fourth is five or six chains wide, and having resisted denudation, it forms the steep hill, Mt. Kirk, on which the leases 532, Norseman Proprietary and 562, Mt. Rugged were situated.

All the original leases became extinct by the end of the year 1897. Two were taken up again, the Italia, G.M.L. 165, became the Italia, 567, and Mt. Kirk, G.M.L. 132 became the Kirkpatrick Mt. Kirk, G.M.L. 554. These became extinct in February, 1899, and December, 1897, respectively. Almost all, except the two most westerly leases have had at least two prospecting shafts, mostly sunk on the underlay, but no particulars of the workings have been recerded, and they were inaccessible at the time of the geographical survey. There appears to be only a single crushing recorded from this part, and there are no signs of any ore having been carted away, but I heard that sundry parcels of ore taken from some of the paddocks at the dumps have yielded half ounce to the ton. The great expense of carting appears to have stopped operations.

Table showing the Yield of the Mt. Kirk Reef.

Year.	Name and No. of lease.	Ore treated.	Gold therefrom.	Remarks.
		tons.	ozs.	
1897 ...	Mt. Kirk, 132	5·00	·90	or ·180ozs. per ton Bevilaqua

Returning now to the north end of the next line of reefs, near the north end of the area mapped.

The Eden Park Reef.

Ridges of banded quartzite and ironstone commence near the south side of the norite belt. Half a mile south they form three ridges. The western one contains the Eden Park Reef that sweeps round diagonally from the central ridge south-westerly to a north and south course; the northern end underlays easterly 70 degrees, as does also another parallel but more broken vein a few chains westerly. The south end underlays to the west. There were here four leases held by the Eden Park G.M. Co.—Eden Park, G.M.L. 133; Eden Park No. 1 South, G.M.L. 134; Eden Park South Extended, G.M.L. 176; and Howestake, G.M.L. 334—of a total area of a little over 49 acres. In these leases a number of underlay shafts were sunk 100 feet and less with drives. Mr. Angove states that the quartz ranged from 2 feet 6 inches to 4 feet in thickness. There are no returns of crushings, and the leases were all void by the end of the year 1898. G.M.L. 133 became in part the Welcome, G.M.L. 732, and was subsequently Q.C. 120. Last Chance, held by D. C. Nieman, and later the Welcome, G.M.L. 918. Half a mile south this line of quartzites divides and pinches out towards the valley crossing the range, where the Israelite Bay track is, but re-appears on the south side.

Table showing the Yield of the Eden Park Reef.

Year.	Name and No. of lease.	Ozs. Dollied.	Tons crushed.	Tons cyanided.	Ozs. therefrom.	Ozs. from crushings.	Remarks.
[illegible]	Welcome 732 ...	...	46·75	...	...	15·00	Bevilaqua
[illegible]	Do. ...	...	106·00	...	...	97·65	
[illegible]	Do. ...	1·20	12·00	...	...	4·80	State Battery
[illegible]	Q.C. 120	...	21·00	...	...	9·59	Do.
		1·20	185·75	...	...	127·04	
						1·20	
						128·24	or ·690ozs. per ton

The Queen of the West Reef.

On the middle line of quartzite and ironstone ridge about half a mile south of the Eden Park, was the Whiteman, G.M.L. 549, of 24 acres, where a shaft is sunk on the top of the ridge on a small quartz vein. South of this was the Mildura No. 4, G.M.L. 392, on which a shaft 75 feet deep was made, when water stopped further sinking. The lease subsequently became Queen of the West, G.M.L. 529, and was forfeited in May, and was subsequently Queen of the West North, G.M.L. 628, which was voided in 1899.

Leases 549 and 628 were subsequently LITTLE JIM No. 1 NORTH, G.M.L. 788, and LITTLE JIM, G.M.L. 786. Both, however, were withdrawn in December, 1899. At the south end of the latter several shafts have been sunk 80 feet and less on some quartz leaders at the head of the Queen of the West gully, where some alluvial gold had been found. The banded quartzite divides into two lines about here. South of these shafts was the QUEEN OF THE WEST, G.M.L. 390. The original prospectors, Messrs. Pugsley and Kelly, found a nugget of several hundred ounces of gold, it is said, only eight inches below the surface on the brow of the hill, near the original underlay shaft, where there are two very short east and west ferruginous quartz reefs. This shaft meets a vertical shaft to the south at a depth of about 70 feet, and follows the south underlay of the reef 35 feet beyond, when a north and south quartz vein was met with, but then so much salt water came in as to stop operations. The workings were inaccessible, but I am informed that at 55 feet a drive goes east 10 feet and west 45 feet; at both ends the quartz cuts out in quartzite crossing it. The reef was one foot wide, pinching out in places, and carrying rich gold. Another shaft about one and a half chains north of this was put down 76 feet. At 50-feet level a crosscut was taken west for 96 feet to ironstone. At 76 feet a crosscut was put it east for 112 feet, cutting a north and south reef, two feet wide of poor value. The lease ceased to exist in 1900; portions of the north end were subsequently held as Q.C. 82 and Q.C. 83 by Messrs Casey and Dobbie up to January, 1904.

Full details of such of the crushings from the Queen of the West Reef as have been recorded are given below.

Table showing the Yield of the Queen of the West Reefs.

Year.	Name and No. of lease.	Ozs. Dollied.	Tons crushed.	Tons cyanided.	Ozs. therefrom.	Ozs. from crushings.	Remarks.
1897 ...	Mildura, 391 ...	...	20·00	...	...	16·50	Bevilaqua
1898 ...	Queen of the West, 390	...	119·00	...	...	255·38	
1899 ...	Queen of the West, 390	2·00	...	...	...	...	
1899 ...	Little Jim, 796 ...	16·56	...	...	...	...	
		18·56	139·00	...	...	271·88 18·56	
						290·44	or 2·089 ozs. per ton.

The Mary Cater Reef.

On the east line of banded quartzites and ironstones was the MARY CATER, G.M.L. 402. Mr. Angove states that a shaft was sunk 30 feet and a crosscut made 25 feet west to banded ironstone and then 8 feet on underlay. This is probably the shaft on the

hillside about 200 feet north of the gully. The well is an underlay shaft, 157 feet deep, near the gully; it yielded at first 250 gallons per hour but has lessened since; the water has been used for stock for many years; an analysis of this is given in Table 1. Another shaft near the north boundary is 22 feet. It was declared that 500 feet sinking and 270 feet driving was done on this and the adjacent leases at an expenditure of £1,500, but there are no returns from the property. The lease subsequently became in part W.R. 160, owned by the Princess Royal G.M. and Mr. R. Pack.

Some alluvial gold has been found in the gully here. South of the original lease a larger gully runs south, in which there has been a large amount of alluvial working; the depth of ground in places was deep enough for driving headings. Where the valley flat begins the silicification of the sandstones has stopped, but their line can be traced for three-quarters of a mile southwards [5514, 5584]. The two gullies between this and the Queen of the West gully have also been auriferous. Several shafts have been sunk on the edge of the flat here, 25 feet or more deep, to try for a deeper bottom, but have penetrated decomposed metamorphic sandstone all the way.

The Mildura Reef.

To the south of the Queen of the West was the MILDURA, G.M.L. 391. An underlay shaft has been sunk 35 feet on a north and south reef, about four feet wide, according to Mr. Angove, which it is said showed fair prospects, but the great influx of salt water stopped operations and it was forfeited in 1896. *See* return.

The Bon Accord Reef.

South of this two lines of banded quartzite and ironstone are to be seen at intervals, covered also in places by ironstone conglomerate. The leases that have been here do not require any special notice until the BON ACCORD REEF is reached; it is an east and west reef, underlaying steeply south.

The BON ACCORD, G.M.L. 95, was here, and a considerable amount of work has been done. This lease was void in May, 1897; it was subsequently BON ACCORD, G.M.L. 623, held by the Bon Accord G.M. Co. It was forfeited in November, 1898; subsequently Q.Cs. 18 and 19, held by Veal and Williams, were taken up on it and held until January, 1899, when the ground was embraced by the BON ACCORD, G.M.L. 730, which was renumbered BON ACCORD, G.M.L. 734. A shaft has been sunk 180 feet on the south underlay of a short east and west reef, which is here five feet wide, with a drive at 100-feet level west to the banded quartzite. Either the reef thins out or else the main body has been missed. Also a shaft 50 feet within a couple of chains to the west, with drives of 25 feet and 30 feet east and west. An open cut has been made near the top of the ridge, also a shaft 40 feet with a drive

40 feet east. Subsequently an unregistered Q.C., held by J. Smith, was taken up at end of the year 1904. On the east side was the Golden Gully, G.M.L. 328.

The Bon Accord reef, as may be seen by a reference to the table below, which gives such details as are available, has returned a little over an ounce to the ton:—

Table showing the Yield of the Bon Accord Reef.

Year.	Name and No. of lease.	Dollied. ozs.	Tons crushed.	Tons cyanided.	Ozs. therefrom.	Ozs. from crushings.	Remarks.
1898 ..	Q.C. 18	...	1·10	...	...	18·22	
1898 ...	Q.C. 19	5·60	...	...	...	...	
1899 ...	Bon Accord, 730 ..	...	37·75	...	...	57·18	
1899 ...	Do, 734...	...	134·00	...	..	108·90	
		5·60	172·85	...	...	184·25 5·60	
						189·85	or 1·098 ozs. per ton.

The Belmont Reef.

There have been alluvial gold workings in the gully north of these leases and also in the one south of it. South of the above lease was No. 1 South Bon Accord, G.M.L. 125, which was forfeited in May, 1897, and subsequently became Bon Accord South, G.M.L. 624, held by the Bon Accord G.M. Co., who sank several shafts; but no particulars are available regarding them.

South of this was the Mount Accord, G.M.L. 439, which eventually became the Belmont, G.M.L. 789. There is scarcely any distinguishable reef at the surface, but two vertical shafts were sunk on the ridge. Q.C. 163, held by Christians and party in 1904, embraced part of the lease. The following figures give the details regarding the yield of the Belmont Reef:—

Table showing the Yield of the Belmont Reef.

Year.	Name and No. of lease.	Dollied ozs.	Ore treated.	Gold therefrom.	—
1899 ...	Belmont, 789 ...	...	6·00	60·00	
1900 ...	Do. ...	20·77	18·50	62·80	
1904 ...	Q.C. 163	25·63	...	...	= 21·59 F.
		46·40	24·50	122·80 46·40	
				169·20	or 6·904 ozs. per ton.

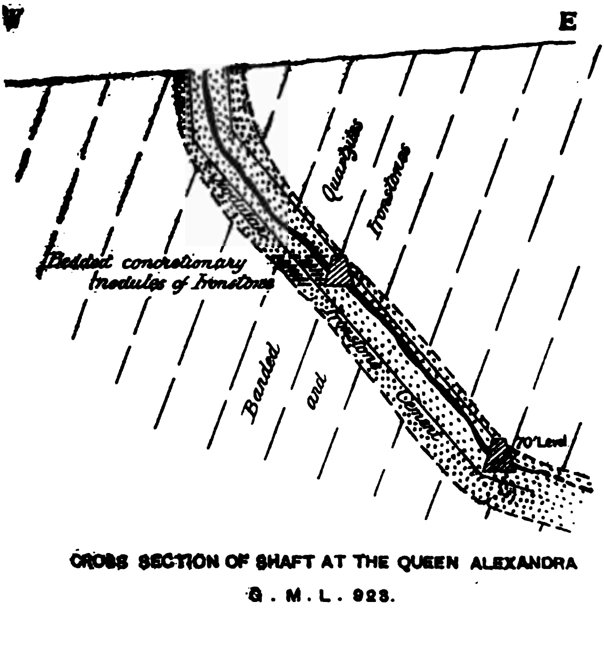
The Albany Reef.

All the gullies running easterly from the Bon Accord to the Narracoorte Gully have been worked by alluvial miners, showing that there must be a considerable amount of gold distributed throughout the lines of banded quartzites and ironstones. On the ridge about 10 chains south-west of the Belmont was the ALBANY, G.M.L. 105, of 12 acres, in which Mr. Angove states an adit was driven 95 feet into the east face of the hill, and a shaft near by was also sunk on its underlay 30 feet. The reef is three feet wide.

The Welcome Reef.

Half a mile south was the WELCOME, G.M.L. 403. There is a reef here 20 inches wide, it underlays east. A few shallow pits were sunk on it, 24 feet, 12 feet, and 8 feet, according to Mr. Angove. It became void in November, 1898, and subsequently Q.C. 158, held by Messrs. Fitzgerald and Hans from a short period in 1904, when it became QUEEN ALEXANDRA, G.M.L. 923. Two shafts were sunk about 70 feet each on this reef. The original ferruginous formation has been converted into a tough ironstone nodules cement at 30 feet depth; the influx of surface water has been sufficient to form saturation zones, causing the cement to form into horizontally bedded nodules. This is shown in accompanying sketch:—

FIG. 16.



CROSS SECTION OF SHAFT AT THE QUEEN ALEXANDRA G.M.L. 923.

The details regarding the yield of the Welcome Reef are given in full in the table below:—

Table showing the Yield of the Welcome Reef.

Year	Name and No. of lease.	Dollied.	Tons crushed.	Tons cyanided.	Ozs. therefrom.	Ozs. from crushings.	Remarks.
1897 ...	Welcome, 403 ...	...	46·75	...	...	15·00	State Battery
1898 ...	Do.	35·00	...	...	...	...	
1904 ...	Q.C. 159	...	5·50	...	...	5·91	= 4·86 F.
1904 ...	Do.	...	...	4·00	·64	...	State Battery
1904 ...	Queen Alexandra, 923	...	8·50	...	...	19·10	= 15·73 F.
	Do.	...	...	6·00	2·96	...	State Battery
		35·00	60·75	10·00	3·60	30·01 3·60 35 00	
						68·61 or 1·129 ozs. per ton.	

The La Mascotte Reef.

The Eden Park line of banded quartzite and ironstone reappears on the south side of the Israelite Bay track, where La Mascotte, G.M.L. 441, was situated. A shaft was sunk 45 feet on a reef here with a crosscut 35 feet east, according to Mr. Angove, and which I was told showed good prospects. It was forfeited in 1896.

The Norseman Star Reef.

In the next lease southerly, the Norseman Star North, G.M.L. 398, the same reef probably outcrops on the ridge, where there is a shaft sunk on some good-looking quartz [5903], which is also said to have shown fair values. South of this again was the Norseman Star, G.M.L. 397, where there is another reef, underlaying east, on which there are two shafts; there is a shaft also at the north end of the lease, the dump of which is wholly composed of ferruginous kaolin. South of this again is the Norseman Star South, G.M.L. 445, which has a shaft on the westerly underlay of a vein of which there are no particulars obtainable.

The Wheel Reef.

The next few old leases appear not to require any special comment until the New Chum, G.M.L. 73, is reached, in which Mr. Angove states there was, in 1896, a vertical shaft 40 feet. This is apparently on the Wheel Reef, which extends for 1,000 feet through several leases southerly, underlaying west with the metamorphic sandstone and quartzite. The lease was forfeited in 1897,

and was subsequently New Chum, G.M.L. 639; later it became in part Wheel North, G.M.L. 823. The next lease southerly was the Florence, G.M.L. 122, of 12 acres. Mr. Angove states that an underlay shaft was sunk 80 feet on the above-mentioned reef, and that it was 8 feet wide; and also a vertical shaft of 34 feet. Subsequently the Florence became in part the Wheel, G.M.L. 822, when a good deal of work was done along this reef. Q.C. 135, which has been held by Daniels and party since July, 1903, also unregistered Q.C., held by Phillips and party in December, 1904, occupied portions of this ground.

Such details as are obtainable as to the yield of the Wheel Reef are given below in tabular form:—

Table showing the Yield of the Wheel Reef.

Year.	Name and No. of lease.	Ozs. dollied.	Tons crushed.	Tons cyanided.	Ozs. therefrom.	Ozs. from crushings.	Remarks.
1898 ...	New Chum, 639 ...	...	9·75	...	...	1·00	Bevilaqua
1899 ..	Do.	...	6·00	...	...	1·70	
1901 ..	Wheel North, 823	...	5·00	...	...	1·37	
1900 ...	Wheel, 822 ...	...	5·00	...	...	17·88	
1901 ...	Do.	...	61·00	...	...	70·10	
1902 ..	Do.	...	7·00	...	...	4·68	
1902 ...	Do.	...	...	4·00	·56	...	State Battery
1903 ..	Unregistered Q.C., Downey	...	16·09	...	...	1·90	Do.
1903 ...	Q.C., 135	...	44·50	...	...	12·98	Do.
1903 ...	Unregistered Q.C., McNeil	...	...	7·00	·96	...	Do.
1904 ...	Unregistered Q.C., Phillips	...	16·50	9·00	1·77	11·92	= 10·52 F.
1904 ..	Do.	5·95	...	...	...	...	= 4·56 F.
		5·95	170·75	20·00	3·29	113·48 3·22 5·95	
						122·72	or ·718 ozs. per ton.

The United Miners' Reef.

Half a-mile south of this was the Daisy, G.M.L. 79, which subsequently became the United Miners, G.M.L. 127, but locally known as the Erl King. An adit has been driven here easterly 196 feet into the banded ironstone, with occasional quartz leaders; also a shaft, which Mr. Angove states is 85 feet on easterly underlay and another 93 feet similar, with a drive 50 feet north and south. The lease became subsequently in part Q.C. 17, held by R. Stevenson, until March, 1899. On the east side of the Daisy the Golden King, G.M.L. 333, had a brief existence, and became in part the Reefton, G.M.L. 833. Part of G.M.L. 333 was subsequently the Norseman Rose, G.M.L. 916.

The details of the United Miners' Reef are given in tabular form below:—

Table showing the Yield of the United Miners' Reef.

Year.	Name and No. of lease.	Dollied.	Tons crushed.	Tons cyanided.	Ozs. therefrom.	Ozs. from crushings.	Remarks.
1897 ...	United Miners, 127	...	·50	...	...	·35	
1899 ...	Unregistered Q.C., Faerie	...	24·00	...	...	17·50	Bevalaqua
1900 ...	Do. ...	...	30·00	...	...	17·45	Norseman G.M.
1901 ...	Unregistered Q.C.	...	12·00	...	...	1·90	
		...	66·50	...	...	37·20	or ·559ozs. per ton.

The Narracoorte Reef.

South of this is the Narracoorte, G.M.L. 161, which was held by the St. Agnes G.M. Co. There is a shaft 130 feet on the west underlay of a reef in the quartzite and ironstone. Two other shafts on the west side of the lease are down 100 feet on a quartz reef underlaying east at a flat angle. At the end of the year 1898 the company stated that there were 800 feet of drives in the mine. The reef is said to have been 2 feet wide; a drive at the 100-feet level connects the two shafts; there is also a drive south 200 feet; stoping also has been done, but I am not able to say how much. The crushing was evidently done at the St. Agnes Co's. battery, and there is no separate record of the results from this reef. The Narracoorte Gully passes through this lease. Both the watercourse and the flat adjacent to it have been worked by alluvial miners. Occasionally nuggets of several pennyweights were obtained.

The Tarpeena Reef.

South of this was the Tarpeena, G.M.L. 192. A shaft was sunk on the banded ironstone to a depth, according to Mr. Angove, of 70 feet, and a crosscut made 40 feet, with a drive of 30 feet, on a reef which does not outcrop. There are also three other minor shafts. The ground was forfeited in 1897 and then became the Tarpeena, G.M.L. 661, which, having been withdrawn in 1897, subsequently became the Tarpeena, G.M.L. 906, when a new shaft was sunk close to the other on a small cross vein showing on the surface underlaying south, accompanied by an ironstone cement, which latter is probably only an altered ferruginous formation, and the other shaft was filled with mullock from the new one.

The details of the crushings from these reefs are given below:—

Table showing the Yield of the Narracoorte and Tarpeena Reefs.

Year.	Name and No. of lease.	Ozs. dollied.	Tons crushed.	Tons cyanided.	Ozs. therefrom.	Ozs. from crushings.	Remarks.
1900 ...	Narracoorte, 161	...	23·00	...	...	6·65	State Battery
1904 ..	Tarpeena, 906 ...	...	89·50	...	...	66·09	= 57·18 F.
1904 ...	Do. ...	2·20	...	...	...	...	= 1·86 F.
1904 ...	Do. ...	...	...	64·82	30·08	...	State Battery
1904 ...	Two Japs, 910 ...	22·50	...	...	...	...	20·19 F.
1904 ...	Unreg. Q.C., Campbell	6·14	...	...	...	...	= 5·62 F.
		30·84	112·50	64·82	30·08	72·74 30·08 30·84	
						133·66	or 1·1880ozs. per ton.

The Lord Hopetoun Reef.

On the west side of the last line of banded quartzites and ironstone is another line commencing on the flat opposite to the Norseman Star South, G.M.L. 445. On this was the Great Bonanza, G.M.L. 560, of 12 acres. One shaft was sunk on the east side of the ironstone.

South of this was the Moonlight, G.M.L. 280. A shaft was sunk here on a reef on the west side. The lease was forfeited in November, 1896. It eventually became the Moonlight, G.M.L. 596, which, having been surrendered in May, 1898, gave place in part to W.R. 145.

South again was the Lone Star, G.M.L. 80, which subsequently became the Caledonia, G.M.L. 313. At this period Mr. Angove states that one vertical shaft was sunk in the ironstone 60 feet, with a drive 15 feet on a reef five feet wide. The Caledonia was forfeited at the close of 1896, and subsequently became the Great Barrier G.M.L. 606, which ceased to exist in 1898. G.M.Ls. 596 and 606 were subsequently the Horseshoe, G.M.L. 844. The banded quartzite here becomes a double line. South again was the Red, White, and Blue, G.M L. 59. The principal shafts were one of 70 feet, with a crosscut 25 feet to lode and another shaft 40 feet on underlay south of a cross reef.

South of this was the Mignon, G.M.L. 78, which has a shaft 50 feet sunk on a cross reef underlaying south, and a vertical 70-feet shaft near the south-west corner of lease. These two last were subsequently part of the Star, G.M.L. 835, which was amalgamated with the Star South, G.M.L. 843, in October, 1901. The latter was

surrendered in March, 1902, and the former was void in April of that year, and became subsequently in part the Vale North, G.M.L. 867. Portions of 867 and 835 became subsequently the Amy Castles, G.M.L. 917. On the west boundary of leases 280 and 835 are outcrops of reef on which some shafts have been sunk, but which do not appear to be auriferous; they may be a northerly continuation of the outlying reef that extends south from the Broomehill, which is described after the St. Alban's reef.

South of this was the Christmas Gift, G.M.L. 64, of 24 acres. The holders of this lease put in an adit 30 feet easterly into the ironstone, and sank a shaft on the hill 90 feet on a reef 18 inches wide, with an underlay of 65 degrees to west—the reef was said to carry very good gold, this was probably part of the Lord Hopetoun Reef—also another shaft 60 feet on the west side of the lease.

South of this was the Leviathan South, G.M.L. 87, where a shaft was sunk 60 feet on the west side of the lease. This having been forfeited in 1895, subsequently became the Leviathan South, G.M.L. 453, and afterwards, in part, Braeside, G.M.L. 854. This latter was surrendered; subsequently a part of it was embraced by Q.C. 149, held by Mr. Mountford. G.M.L. 64 became subsequently in part the Edinburgh Castle, G.M.L. 686, held by the new Queensland Norseman G.M. Co. They utilised the previous Christmas Gift shafts and made the main shaft 180 feet; the middle shaft 70 feet, and the north shaft 40 feet. The main shaft had short drives at 50 feet, 80 feet, and 100 feet. The Company had a three-head battery here. The lease was forfeited and subsequently became the Absent Minded Beggar, G.M.L. 811, but which was withdrawn in 1900, and part was applied for in April as the Lord Hopetoun, G.M.L. 819; subsequently in part Q.C. 70, held by S. McGonnigal up to March, 1901. The Q.C. Blowfly was here held by Messrs. Taylor and Fowler. The ground was applied for in 1901 as the Lord Hopetoun, G.M.L. 839, and was forfeited in February, 1902. The Lord Hopetoun, G.M.L. 858, was applied for in May, 1902. The mine was then opened up afresh; the main shaft which had been half filled up was being cleared out at the time of my inspection, and stoping at the 80 feet level north of the shaft was in progress, whilst south of the shaft from the 50 feet level the reef has been stoped out to the surface. The remainder of the G.M.L. 819 not occupied by 858, became the Lord Hopetoun Extended, G.M.L. 924. The northern portions of G.M.L. 686 and portion of G.M.L. 78 became Q.C. 71, The Comet, held by T. J. Earle up to March, 1902; this was north of the Lord Hopetoun shaft; it was merged into the Vale, G.M.L. 838. A shaft is here down 180 feet. This subsequently was the Admiral Togo, G.M.L. 919, which later on was in part the Alma, G.M.L. 940, and is still in force (Fig. 17).

Portion of G.M.L. 835 and G.M.L. 843 became the Vale North, G.M.L. 867.

Photo., W. D. CAMPBELL.

Govt. Photo. Litho.

The various details obtainable regarding the Lord Hopetoun Reef are given in tabular form in the return below:—

Table showing the Yield of the Lord Hopetoun Reef.

Year	Name and No. of lease.	Ozs. dollied.	Tons crushed.	Tons cyanided.	Ozs. therefrom.	Ozs. from crushings.	Remarks.
1901 ..	Star, 835	...	15·60	...	...	3·23	
1901 .	Horseshoe, 844 ...	...	31·00	...	...	13·51	State Battery
1902 .	Do. ...	...	10·00	...	...	4·50	
1902 .	Do. ...	...	...	15·00	4·16	...	Do.
1897 .	Edinburgh Castle, 686	...	9·50	...	...	6·66	
1898 .	Do. ...	...	55·25	...	...	11·33	
1899	Do. ...	...	46·00	...	...	14·40	Bevilaqua
1899 ...	Do. ...	...	...	58·00	6·37	...	State Battery
1900 ...	Absent Minded Beggar, 811	...	49·50	...	...	42·00	Bevilaqua
1900 ..	Do. ...	...	...	27·00	3·15	...	State Battery
1901 .	Q.C., Blowfly ...	...	16·00	8·00	1·25	11·82	Do.
1901 ..	Q.C., 71, Comet ...	...	24 00	7·00	1·14	18·46	Do.
1901	Vale, 838	...	22·00	...	...	64·08	
1902	Do. ...	...	108·00	...	...	123·42	
1902 .	Do. ...	...	...	63·50	13·30	...	Do.
1903	Do. ...	...	123·00	...	...	97·09	
1903 ...	Do. ...	...	...	54·50	14·23	...	Do.
1900 .	Q.C., 70	...	37·50	...	..	33·00	Bevilaqua
1900 .	Q.C., 72	...	7·00	...	...	3·50	State Battery
1901 ..	Lord Hopetoun 819	...	74·00	...	...	42·59	
1901 ...	Lord Hopetoun 839	...	63·00	...	...	35·77	
1902 .	Lord Hopetoun 858	...	47·00	...	...	40·77	
1902 .	Do. ...	...	...	14·00	1·35	...	State Battery
1903 ..	Do. ...	...	160·00	...	...	82·44	
1903 ..	Do. ...	...	...	15·00	1·99	...	State Battery
1904 .	Do. ...	...	332·00	...	...	233·97	=208·55 F.
1904 .	Do. ...	...	...	20·50	4·32	...	State Battery
1904 .	Lord Hopetoun Leases, 858, 919, 924	...	122·50	...	...	78·85	=68·18 F.
1904 ..	Do. do.	3·92	...	...	...	...	=3·22 F.
1902 ...	Braeside, 854 ...	...	36·00	...	...	22·95	
1902 ..	Do. ...	...	...	28·00	4·12	...	State Battery
1903 ..	Q.C., 149 on 854 ...	...	17·00	...	...	55·00	Do.
1904 ..	Do. ...	...	20·00	...	...	7·65	=6·47 F., State Battery
1904 .	Amy Castles, 917	...	24·78	...	...	24·78	=20·90 F.
		3·92	1,330·03	310·50	55·38	1,071·77 55·38 3·92	
						1,131·07	or ·85ozs. per ton

St. Alban's Reef.

The line of reef outcrops that are along this line of banded quartzites at intervals from south of the Leviathan South to the Narracoorte, a distance of half a mile, is here designated the St. Alban's Reef. It underlays to the east and shows a strong body of stone at the Hit or Miss, where it has been tested to a vertical depth of 100 feet, and also probably to the same depth in the Narracoorte.

On this line of country was the St. Albans, G.M.L., 55. Mr. A gove states that this was the first lease taken up on this line of ir istone country, and that four shafts were sunk, No. 1 vertical 4 feet, with drive north-east, at bottom 35 feet long. No. 2, 30 feet

on westerly underlay of a reef 15 inches wide, with ferruginous quartz and ironstone. Nos. 3 and 4, 60 feet each, ditto on a very white quartz reef 2 feet wide. The St. Albans subsequently became Q.C. 154, GOLDEN BUG, held by Messrs. Kirwan and Daniels for two months in 1904, and later Q.C. 160, GOLDEN BUG, held by Steiss and Miller from April to September, 1904. These were on two east and west veins of quartz underlying 35 degrees to south, width 18 inches, both low grade stone. South of this was the ST. ALBANS NO. 1 SOUTH, G.M.L. 61. Mr. Angove states that the adit which had been driven into the hill easterly 200 feet, gave very good prospects. At 100 feet from the mouth, there is an ironstone formation underlying 70 degrees to west on which there is a short drive. There are also too shafts of 30 feet and 31 feet depth. Part of the ground was subsequently known as the WESTRALIA LONG TUNNEL, G.M.L. 820, whilst later the BANDIT KING, G.M.L. 837, occupied portions of it and the UNITED MINERS, G.M.L. 127, already mentioned. Subsequently in part it became Q.C. 139 and Q.C. 130 held by Hann and party until December 1903.

On the last line of leases a strong body of quartz was opened up, underlaying east 52 degrees, by two shafts 150 feet each, and another to the north of these 75 feet with drives and stoping. The oxidised rock on the west side of the outcrop has also yielded some good patches of gold [5957]. It subsequently became UNREG. Q.C. held by J. Young, whilst a portion became Q.C. 154, held by Kirwan and party, and eventually they became the HIT OR MISS, G.M.L. 863, and were still in force at the time of writing.

The St. Albans Reef crushings are given in detail below :—

Table showing the yield of the St. Alban's Reef.

Year.	Name and No. of lease.	Ozs. dollied.	Tons crushed.	Tons cyanided.	Ozs. therefrom.	Ozs. from crushings.	Remarks.
1900 ...	Westralia Long Tunnel, 820	...	40·00	...	...	6·06	
1901 ...	Do. ...	...	16·00	...	...	5·35	Norseman G.M.
1903 ...	Q.C. 129	24·44	26·00	...	...	6·79	State Battery
1904 ...	Q.C. 154 on 55 ...	...	12·50	...	...	24·44	Do.
1904 ...	Q.C. 160, Golden Bug	...	18·00	...	...	14·51	= 12·07 F.
1904 ..	Do.	21·24	..	...	...		= 19·45 F.
1901 ...	Bandit King, 837	...	91·00	...	...	83·53	
1901 ...	Do. ...	...	...	28·00	6·94	..	State Battery
1902 ..	Do. ...	...	60·00	...	...	34·35	
1902 ...	Unregistered Q.C., Young, on 837	...	56·50	41·50	13·17	48·50	Do.
1902 ...	Hit or Miss, 863 ...	...	21·00	...	...	10·12	
1902 ...	Do. ...	...	...	22·50	5·29	...	Do.
1903 ...	Do. ...	...	31·00	...	...	·10·51	
1903 ...	Do. ...	...	...	6·00	1·93	...	Do.
1904 ...	Do. ...	...	12·50	...	...	5·75	= 4·73 F.
1904 ...	Do. ...	...	...	9·00	1·32	...	State Battery
1904 ...	Q.C., Peake, on Mt. Gambier, 384	...	6·50	...	...	2·15	=1·77 F. State Battery
1904 ...	P.A., 47	...	18·50	6·00	·73	8·29	
		45·68	409·50	113·00	29·38	260·44 29·38 45·68	
						335·50	or ·819 ozs. per ton.

The Ziegler's Find and adjacent Lodes.

The line of banded quartzites and ironstone west of the Hit or Miss pinches out suddenly, and for half-a-mile southward is represented only by some narrow patches, but makes again strongly beyond that point, with a large quartz reef near its western margin.

About 15 chains west of the St. Alban's, there is another north and south reef, which has a very broken continuity for upwards of two miles along the western side of the western ridge of the banded quartzites; it underlays west; there are no crushings recorded from it. The depths of the shafts, as obtained from Mr. Angove's report, are as follows:—The northern end appears in the Broome Hill, G.M.L. 394, where there are two small shafts 20 feet and 10 feet on the underlay. In the next lease to the south is St. Alban's West, G.M.L. 443. It appears as two parallel reefs trending south-easterly, the course being apparently deflected by the presence of a quartz porphyry dyke that occurs to the south of the two principal shafts. In October, 1896, the owners declared that there were four shafts, 106 feet, 55 feet, 27 feet, and 25 feet deep.

Next south is the Albert Edward, G.M.L. 331. There were two shafts, one 30 feet on a reef one foot thick, the other 35 feet on a reef four feet wide.

Next south is the Mt. Gambier, G.M.L. 384, where the reef outcrops in a huge mass of very white quartz, underlying 55 degree west. A shaft 40 feet has been sunk near its western side, and another 6 chains north-westerly on a small reef.

Next south is the Blue Ensign, G.M.L. 372, in which the reef again outcrops. There are two shafts, 50 feet and 10 feet. Mr. Angove states that the reef is 4 feet wide in the former. All these leases were void in December, 1897.

Next south is the Holstein North, G.M.L. 510. There are two parallel reefs here to the northward of the Norseman to Government tank road. A shaft has been sunk on the underlay of each reef. The quartz has a dark, clouded-blue tint.

In Block 512, about a quarter of a mile farther south, the reef again appears, and four shafts have been sunk on it, but no details are available.

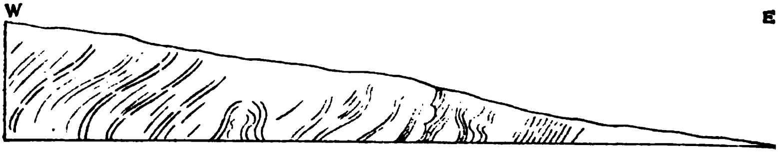
Half-a-mile farther south, several shafts have been sunk on the reef at the south end of the Lady Bella South, G.M.L. 766, but no details are available; also in McDonough's Find, G.M.L. 348, occupying the junction of the ridge forming the watershed to north and south with the westernmost of the banded ironstone and quartzite ridges. There appear to be two reefs, at least here, on which shafts have been sunk; one is on the western margin of the banded formation underlying 62 degrees to west.

South of this was the PIRIE WEST, G.M.L. 345, which was forfeited in May, 1896; it was known as the PINE WEST, G.M.L. 540.

South of this was HOLSTEIN No. 1 NORTH, G.M.L. 222. A shaft is here on another outcrop of the same reef, at the south end of this lease.

From here to the W.R.'s 127, 131, 159, at Sawpit Gully, a distance of three-quarters of a mile, there were several leases in which some shafts were sunk on these westerly lying reefs without success. The south-east corner of Block 512, alluded to above, adjoining the NEW YEAR'S GIFT, G.M.L. 406, was void in December, 1897, and subsequently became the LADY BELLA NORTH, G.M.L. 765, and LADY BELLA, G.M.L. 764. In each of these a shaft was sunk and an adit was commenced; no details are available of the former. The accompanying Fig. 18 shows the convolutions of the ferruginous bands in this formation. Both

FIG. 18.



DECOMPOSED BANDED QUARTZITE AND IRONSTONE. LADY BELLA Nᵀᴴ G.M.L. 765.

leases were forfeited in August, 1901. Q.C. 159, was taken up here by O'Leary and Howell in 1904.

South of this was the BRITANNIA, G.M.L. 518, which was subsequently in part LADY BELLA SOUTH, G.M.L. 766. Four shafts were sunk here on the underlay on a reef on the east boundary, also two near the south-west corner, which have been already alluded to. The lease became subsequently in part ZIEGLER'S FIND, G.M.L. 907, and is still in force. The workings comprise open cuts and shallow shafts in the eastern slope of the banded ironstone formation, at a saddle between gullies trending north and south, in each of which a little alluvial gold has been found. Here some quartz veins intersect the ironstone horizontally, and are gold-bearing where the ironstone bands are reached; the adjacent rock or its representative ferruginous kaolin being also auriferous [5991]. The shoot of gold has a direction of 225 degrees. A small fault of about two feet runs in a direction of 308 degrees across the workings. On the east side of the next ridge, and north of the sawpit, is a gully where some good alluvial workings have been; the gold has evidently been shed from an auriferous reef in the ironstone ridge. The whereabouts of its source has not yet been found, but the writer was informed that some leaf gold has been found in veins at the head of this gully.

The table appended shows the yield of the reefs alluded to above :—

Table showing the Yield of the Ziegler's Find and adjacent Lodes.

Year.	Name and No. of lease.	Ozs. dollied.	Tons crushed.	Tons cyanided.	Ozs. therefrom.	Ozs. from crushing.	Remarks.
1899 ...	Lady Bella No. 765	3·45	...	...	...	...	
1900 ...	Do. ...	...	1·00	...	...	1·85	
1899 ...	Do. 764	...	29·00	...	...	300·90	
1900 ...	Do. ...	...	36·50	...	...	9·55	
1904 ...	Ziegler's Find, 907	...	78·00	...	...	354·68	= 334·83 F.
1904 ...	Do. ...	...	...	16·83	22·08	...	= 16·83 F.
1904 ...	Do. ...	35·25	...	...	...	...	= 32·21 F.
1897 ..	Holstein No. 1, 222	...	10·00	...	...	3·50	Bevilaqua
		38·70	154·00	16·83	22·08	670·48	
						22·08	
						38·70	
						731·26	or 4·748ozs. per ton

The Oriental Reefs.

On the south side of Sawpit Gully, laterite deposits cover a considerable portion of the ridges. Between the two is Salvado's Gully and its branch Morelli's Gully, where some of the best alluvial workings in the district have been situated. No work was being done on them at the time of this survey. None of the workings seem to have been more than about 10 feet deep; the bottom was, I understand, an ironstone cement. It does not seem quite clear that this has been tested to a greater depth. The very considerable amount of gold obtained here probably had its source in veins, reefs, and the ferruginous bands in the metamorphic sandstones and quartzites, but the present indications do not appear adequate for the returns. There is a ferruginous and auriferous reef on the saddle at the head of Morelli's Gully that has a north and south direction along the west ridge and skirting the quartzite and underlaying west. The north end has been re-opened up by Mr. Ziegler. Possibly further prospecting will disclose richer reefs; if not, then the gold must have been disseminated through the ground that has been denuded in the course of time. The same may be said in regard to the northern watershed of Raggedy Gully adjacent.

Of the leases taken up along this country, the Morrell, G.M.L. 666, was about one-third of a mile south of Sawpit Gully. In October, 1898, it was void; subsequently in part the Trump Card, G.M.L. 768. Two shafts were sunk here on the saddle at the head of Morelli's Gully, on the above-mentioned quartz reef; particulars not obtainable. It was forfeited in 1900, and subsequently became Trump Card, G.M.L. 804, and later on in part the Morrell, G.M.L. 911. At the head of Salvado's Gully was the Oriental-Norseman G.M. Company's blocks, viz., Oriental, G.M.L. 69; Oriental No. 1 North, G.M.L. 70; Oriental Block,

G.M.L. 370; and ORIENTAL No. 1 NORTH BLOCK, G.M.L. 371, taken up mostly in 1894, having a total of 73 acres. This company made an adit in G.M.L. 69, 420 feet into the ridge westerly to the most solid part of the banded quartzite intersecting a quartz vein and the ironstone lode already referred to; the latter was driven on north. The end of the adit connected with a shaft at the top of the ridge. In G.M.L. 70, an adit 70 feet and a shaft 40 feet were made, and in G.M.L. 371, a shaft was sunk on a small quartz outcrop. These leases became void in 1897, G.M.L. 70 becoming two years later the ALICKAZANDER, G.M.L. 770, when another shaft and open cuts were made along the cap of the reef and auriferous ironstone along the ridge. The lease was subsequently in part LADY MILLAR EXTENDED, G.M.L. 876, when the ridge workings were extended. About this time a quartz outcrop crossing the south boundary was also opened up, and, it is said, with fair results, as may be seen in the table of returns appended. The lease became an UNREGISTERED Q.C., held by Lyons and party, who continued some of the previous open cuts, and obtained a little gold. Since my survey this ground has been taken up by the Lady Mary G.M. Co. as the LADY MILLAR, G.M.L. 928, and is still in force. It includes the southern portion of the lode already referred to. South of the 876 was the CLARENCE, G.M.L. 75, occupying the head of a gully running southerly, where this line of banded formation divides into two lines. An adit 90 feet was driven easterly into the banded ironstone ridge, and a shaft sunk 40 feet. South of this was the ANCHOR, G.M.L. 74, on which two shafts of 40 feet and 18 feet were made, and several open cuts on small reefs. These two leases were subsequently in part the ORIENTAL SOUTH EXTENDED, G.M.L. 491, and became in part the LADY JEAN, G.M.L. 748, and subsequently in part the LADY MARY EXTENDED NORTH, G.M.L. 795, when two shafts of 35 feet and 50 feet were sunk in the banded ironstone formation. Afterwards it became the PERSEVERANCE, G.M.L. 866 [6023].

The south corner of G.M.L. 491 was subsequently part of the LADY MARY NORTH JUNCTION, G.M.L. 718, subsequently the LADY MARY EXTENDED, G.M.L. 762. Two shafts were sunk on a reef in the amphibolite forming the valley of the north arm of the Lady Mary Gully. The southernmost shaft is 158 feet on an underlay of 35 degrees, with quartz six inches to three feet thick, and the other shaft about 150 feet distant north-easterly is not so deep, on an underlay of 45 degrees, with quartz six inches to one foot thick; both have drives and stoping. The quartz has very much the appearance of the Lady Mary Reef.

About a quarter of a mile east of G.M.L. 762 was the GREAT EASTERN, G.M.L. 448. There is an outcrop of a reef two feet wide having an underlay of 20 degrees northerly. A shaft has been sunk and an open cut made. The country rock is a metamorphosed sandstone.

South of this was the LADY MARY NORTH EXTENDED, G.M.L. 359, occupying both the western branch of banded formation and

also the next line westerly. Later the lease became part LADY MARY NORTH No. 1, G.M.L. 713, and afterwards the LADY MARY NORTH EXTENDED No. 1, G.M.L. 719; subsequently it became the NEW NORTH MARY, G.M.L. 763. G.M.L. 713 was subsequently the HOSKING, G.M.L. 793, which is the northernmost of the amalgamated leases of the Lady Mary G.M. Such details of the yield of the Oriental reefs as are obtainable are given *in extenso* in the table below :—

Table showing the Yield of the Oriental Reef.

Year.	Name and No. of Lease.	Ozs. Dollied.	Tons crushed.	Tons cyanided.	Ozs. therefrom.	Ozs. from crushings.	Remarks.
1897 ...	Morrell 666 ...	77·50	...	...	...	...	
1899 ...	Trump Card 768	...	10·00	...	...	11·55	
1900 ...	Do. ...	...	14·00	...	...	5·25	
1904 ...	Morrell 911 ...	24·01	...	...	...	...	
1898 ...	Unregistered Q.C., Oriental	...	17·25	...	...	45·00	Bevilaqua
1898 ...	Lady Jean (Salvado's) 748	...	52·50	...	...	31·50	
1899 ...	Do. ...	...	22·00	...	...	1·60	
1899 ...	Alickazander 770	...	9·50	...	...	3·33	State Battery
1900 ...	Do. ...	...	502·00	...	...	289·52	
1901 ...	Do. ...	...	214·00	...	...	54·67	
	Do. ...	...	...	57·00	12·46	...	State Battery
1902 ...	Do. ...	22·19	21·00	...	...	8·03	
1903 ...	Lady Millar Extended	...	84·00	...	...	54 70	
1904 ...	Do. ...	...	36·50	...	...	7·04	= 5·80 F.
	Do. ...	...	...	17·00	2·49	...	State Battery
1904 ...	Unregistered Q.C. Lyons on Lady Millar Extended	...	41·00	...	...	22·81	= 19·71 F.
	Do. ...	...	...	9·00	1·22	...	State Battery
1904 ...	Unregistered Q.C. J. Matthews	...	5·00	...	...	7·20	= 6·77 F.
1900 ...	Lady Mary Extended, 762	...	177·00	...	...	86·64	
1901 ...	Do. ...	...	55·00	...	...	16·69	
1902 ..	Do. ...	...	...	...	...	...	
1903 ...	Do. ...	...	25·00	...	...	9·00	
		123·70	1275·75	83·00	16·17	656·44 16·17 123·70	
						796·31	or ·624 ozs. per ton

The Stella May.

Raggedy Gully has its source in the Lady Millar lease, after leaving the south side of which it turns east, and at the foot of the main ridge it is joined by the Little Raggedy Gully. A considerable amount of gold has been obtained from both. There are alluvial workings along the course of the gully for a distance of three-quarters of a mile easterly to the line of the easternmost ridge, where the STELLA MAY, G.M.L. 801, was situated. The application for this lease was withdrawn in the early part of 1900, and the ground became subsequently Q.C. 151, held by Geo. Decker, up to February, 1904. Here four or five shafts have been sunk, the main shaft is 100 feet deep, also open cuts made in an altered sandstone, in which

some good patches of gold have been found. No reef or lode is discernable; the gold occurs in patches only in the sandstone. The lay of this sandstone is mostly 20 degrees to the north. It has a bluish grey tint mottled with brown; the latter colour predominates, I was told, towards the base of the deposit, which is apparently conformable to and rests on the banded ironstone.

Table showing the Yield of the Stella May Workings.

Year.	Name of Lease and No. of Lease.	Alluvial.	Dollied.	Ore crushed.	Gold therefrom.
		ozs.	ozs.	tons.	ozs.
1900 ...	Stella May, R.C. 6	141·13	9·00	58·00	60·04
					9·00
					69·04 or 1·190 ozs. per ton

The Lady Mary Reef.

The LADY MARY REEF is a north and south reef, except at the south end; it underlays east from 45 to 80 degrees; it outcrops and has been worked for a length of 1,500 feet and followed to a depth of 360 feet vertically; it ranges up to six feet thick, with an average of about a foot. At the south end of the north and south reef, a break of about 300 feet occurs, after which it turns westerly, and here rich pockets ofgold have been found (Fig. 19). The reef was discovered by S. W. Pearce, on 29th October, 1894, and a lease of 18 acres (G.M.L. 49) applied for by this prospector's mate, George Prout, on behalf of Geo. Brookman.

The other leases of the Lady Mary G.M. are LADY MARY NORTH, G.M.L. 99, LADY MARY, G.M.L. 49, LADY MARY SOUTH, G.M.L. 864, LADY MARY BLOCK CLAIM No. 1, G.M.L. 635, LADY MARY BLOCK CLAIM No. 2, G.M.L. 636, all 12-acre blocks excepting the original one—total 78 acres.

This reef outcrops along the western side of the leases; the older workings for a length of 1,200 feet were worked to a varying depth of about 100 feet during the earlier period of its existence by means of five underlay shafts. These old workings were not readily accessible; portions that I did see, near the small adit, showed two feet to four feet of quartz in the face of the workings. No. 1 shaft is 273 feet on the underlay, but no values were obtained below 100 feet. The main incline shaft No. 7 is the northermost one on this outcrop; it has an underlay of 49 degrees to the first level, and then about 60 degrees to 470 feet, its present depth. The reef varies from two inches to five feet in thickness. A horizontal chute of pay ore occurs in the old workings and extends as far north as the vertical shaft, where another chute about 500 feet in length occurs, rather less in width than the other, and dips to the northward. The 430-feet level was driven along only a slight seam or formation in

Photo., W. D. CAMPBELL. Govt. Photo. Litho.

Lady Mary G.M., looking south, showing banded quartz and ironstone ridge on right.

the country rock for a considerable portion of its length, and the reef was found again making underfoot in the line of the chute. This was followed 40 feet by means of a winze where the reef becomes four feet wide; the value is ½oz. per ton. Adding this 500 feet of chute to the previously-mentioned 1,500 feet, makes a total of 2,000 feet of reef that has been worked in this mine.

The boundary of the banded ironstones and quartzites approaches the outcrop of the quartz near the main vertical shaft at the north end of lease 49, some very rich ore being met with in the open cut. This vertical shaft No. 6 has a depth of 198 feet. No. 2 level is being extended southwards to tap the unworked portion of the reef below the No. 1 level. The quartz is ferruginous in places and in others is laminated, and has mostly one or other of its walls well defined. The undecomposed amphibolite is met with at about 190 feet; it is slightly schistose adjacent to the reef. At the southern end of the workings the undecomposed amphibolite outcrops, and is coarsely crystalline at the south shaft. It alters to actinolite rock about five chains to east, with bands of ironstone. The mine has very little water; what there is, though inferior for the purpose, is used for boiler purposes, *see* 636B, Table 1, for analysis. The following analysis also has been made by Mr. Simpson of the scale resulting from the use of this water from the boilers, which shows that the scale contains 63 per cent. of common salt and 25 per cent. of calcium sulphate.

Analysis of Boiler Scale from Lady Mary G.M., G.S.M. 6045, G.S.L. 1220B:—

Silica, SiO_2	·57 per cent.
Carbonic Anhydride, CO_2	·09
Sulphuric Anhydride, SO_3	16·10
Chlorine, Cl	39·96
Combined Water, H_2O	2·87
Iron and Alumina (Fe Al), O_3 ...	·18
Soda, Na_2O	33·51
Potash, K_2O	·18
Magnesia. MgO	2·12
Lime, CaO	10·32
Hygroscopic Water, H_2O	3·43
	109·33
Less O = Cl	8·99
	100·34

Crushing was commenced with 10 head of stamps and was subsequently increased to 20 head and five cyanide vats. The ore is free milling, the only sulphides appearing at the lower levels.

In the treatment of the tailings and slimes, the best results are obtained by thoroughly sun-drying the slimes and breaking up by a roller by horse power, and placing thin layers alternately of the resulting powder and sands in the cyanide vats. Attention wa

called to this in the State Mining Engineer's Report for 1903, p. 55. Water for the battery is pumped through a three and a-half inch pipe, a distance of one and three-quarter miles from a well and trench at Lake Dundas, vertical lift of about 200 feet. The workings at the north end of this mine are shown in Plate IV., which is from a compass survey.

The crushings from the Lady Mary Reef are given detail in the table below.

Table showing the Yield of the Lady Mary Reef.

Year.	Name and No. of Lease.	Dollied.	Tons crushed.	Tons cyanided.	Ozs. therefrom.	Ozs. from crushings.	Remarks.
1898 ...	Lady Mary South G.M. Co., 77	...	80·00	...	...	96·30	
1899 ...	Lady Mary South G.M. Co., 738-9	...	150·00	...	...	45·50	
1900 ...	Do. ...	...	20·00	...	...	13·00	
1898 ...	Lady Mary South G.M. Co., 49	...	3799·50	...	...	4918·25	
1899 ...	Lady Mary North, 713	...	12·00	...	...	3 00	
1898 ...	Lady Mary Leases, 49, 99, 635, 636	...	9346·00	...	...	8799·66	
1900 ...	Do. ...	...	2333·00	...	...	1935·55	
1901 ...	Do. ...	...	347·00	...	...	2548·27	
1902 ...	Do. ...	...	789·00	...	...	1375·29	
1903 ...	Do. ...	...	805·00	...	...	693·61	
1904 ...	Do. ...	...	527·00	...	...	487·45	= . Silver; = 403·43 F.
1904 ...	Do. ...	...	...	sands. 296·00	66·67	...	= 48·78 F.
1904 ...	Do. ...	...	...	slimes. 202·00	48·14	...	= 35·22 F.
1904 ...	Lady Mary G.M. Co., 49, 99, 635, 636	...	1096·00	...	...	523·85	= 445·21 F.; 10·00 Silver
				sands. 536·00	138·81	...	= 107·35 F.
				slimes. 1093·00	223·15	...	= 174·40 F.
			19344·50	sands. 832·00	205·48	21439·73	
				slimes. 1295·00	271·29	205·48 271·29	
						21916·50	or 1·138ozs. per ton

The Lucky Call Reef.

On the west side of Lady Mary South, G.M.L. 864, is the Lucky Call, G.M.L. 856. The original holders, Slater Bros., found a pocket of 400ozs. of gold close up to the surface and sank a shaft on a quartz formation, underlaying 70 degrees south, also an open-cut on the outcrop of the reef, but finding nothing of value they sold out to Salter and Sinclair for £5, who worked for about eight months before they struck gold in the lode. This was on the west

side of the original shaft at a depth of 25 feet where the reef, 15 inches wide, passed through an ironstone band and changing to 40 degrees underlay, course 295 degrees, and a width of 10 inches, carrying very rich gold. The quartz is very dark, being mixed with ironstone [6016]. A ferruginous casing 6 inches thick flanked each side of the reef; the bottom casing also carries gold, about 1oz. to the ton. The workings are all in oxidised grounds, evidently amphibolite, and bands of ironstone. A new shaft on the west of the first one connects with the workings. This reef is probably a continuation of the Lady Mary reef, which has been deflected round the hard rock that forms the spur eastward from the north corner of this lease. Barry's Gully, which runs easterly from this lease, has been worked for auriferous alluvial for a length of about 16 chains east of the road.

The details of the crushings from this reef are given below.

Table showing the Yield of the Lucky Call Reef.

Year.	Name and No. of lease.	Dollied.	Tons crushed.	Ozs. therefrom.	Remarks.
		ozs.		ozs.	
1902 ...	Lucky Call, 856 ...	180·95	9·25	218·10	
1903 ...	Do. ...	431·05	36·00	64·83	
1904 ...	Do. ...	...	56·00	200·75	= 187·73 F.
		554·09	...	...	= 518·67 F.
		1,166·09	**101·25**	483·68	
				1,166·09	
				1,649·77	or **16·294** ozs. per ton.

The Battler Reef.

On the west side of the Lucky Call was La Mascotte, G.M.L. 857. A shaft was sunk vertically, ending with a few feet of underlay to the south; total depth, about 50 feet. This was on a quartz leader, and it was followed by a drive south-westerly till a cross vein was met with. The 212·85ozs. of gold which was returned as from this ground was found subsequently to be quite unreliable, and the prosecution which resulted fell through only on a technical point. The lease subsequently became the Alphador, G.M.L. 904. The shaft was being deepened at the time of my visit, with the expectation of picking up the continuation of the Lucky Call reef. On the west side of the last is the Alphador West, G.M.L. 933. This lease has been applied for since the writer was on the ground. It is situated on the western boundary of the banded ironstone and quartzite. South of the Alphador, and part of the Lucky Call, is the Battler, G.M.L. 920, which occupies most of the ridge, where

a shaft has been sunk on the south saddle, and from which was obtained 4·85ozs.—4·08 fine—of gold by dollying, during 1904:—

Table showing the Yield of the Battler Reef.

Year.	Name of lease.	No. of lease.	Ozs. Dollied.	Remarks.
1904 ...	Battler	920	4·85	= 4·08 F.

The following table, gives in a synoptical form, the yield of the different reefs alluded to above:—

Synoptical Table showing the Yield of the Norseman Reefs up to the end of 1904.

Name of Reef.	Ore treated.	Gold therefrom.	Rate per ton.
	tons.	ozs.	ozs.
Agnes Venture	259·50	158·99	·614
Bonanza	568·50	1,059·44	1·863
Cumberland and Mt. Benson John Bull	12,846·55	16,345·52	1·272
Desirable	5,197·50	4,182·19	·804
Excelsora Magna	30·00	7·61	·254
Federation	270·00	507·12	1·878
Golden West	94·50	61·77	·654
Hidden Treasure	218·00	176·94	·811
Kirkpatrick Reefs...	1,616·00	1,778·01	1·100
Lady Jean	1,629·00	2,767·76	1·695
Lily	635·75	324·54	·501
Lone Hand	150·00	16·50	·110
Lucky Hit	260·00	150·43	·578
Maloney	764·25	430·94	·563
Mararoa	4,581·12	5,443·00	1·188
Mararoa (various)	...	1,216·65	...
Mary Eileen	16·50	8·11	·491
Mt. Barker	714·20	354·50	·494
Mt. Kirk	5·00	·90	·180
Nellie May	135·00	1,547·10	11·460
Northern Star	2,111·55	2,263·09	1·072
Norseman	84,833·50	55,528·95	·654
O.K....	262·50	290·42	1·104
Ophir	840·75	990·19	1·177
Oversight	43·50	95·63	2·198
Princess Royal	112,602·50	135,048·87	1·199
Q.C. 103	30 00	14·11	·470
Record	121·00	136·81	1·131
Recoupe	325·00	533·87	1·643
St. Patrick	707·40	1,575·05	2·226
Star of Erin	177·50	107·34	·605
Three Colonies	407·00	351·59	·864
Union	1,343·90	975·20	·725
Valkyrie	3,168·50	3,130·85	·988
Venture	508·50	623·41	1·226
Virginia	8·00	3·94	·496
Wilgena	26·00	5·30	·204
Yield of Reefs in the Amphibolite Area	237,508·47	238,210·52	1·003

Synoptical Table showing the Yield of the Norseman Reefs up to the end of 1904—continued.

Name of Reef.	Ore treated.	Gold therefrom.	Rate per ton.
	tons.	ozs.	ozs.
Battler	...	4·85	...
Belmont	24·50	169·20	8·694
Bon Accord	172·85	189·85	1·098
Eden Park	185·75	128·24	·690
Lady Mary	19,244·50	21,916·50	1·139
Lord Hopetoun	1,330·03	1,131·07	·850
Lucky Call	101·25	1,649·77	16·294
Narracoorte	112·50	133·66	1·188
Norseman Rose	...	19·84	...
Oriental	1,275·75	796·31	·624
Queen of the West	139·00	290·44	2·089
St. Alban's	409·50	335·50	·819
Stella May	58·00	69·04	1·190
United Miners	66·50	37·20	·559
Welcome	60·75	68·61	1·129
Wheel	170·75	122·72	·718
Ziegler's Find	154·00	731·26	4·748
Yield of Reefs in the Metamorphic Area	**23,505·63**	**27,794·08**	**1·182**
Total Yield of Reefs in both Areas	**261,014·10**	**266,004·60**	**1·019**

General.

In conclusion, the author would say that in the light of the facts that have been ascertained, there is fair reason to expect satisfactory returns from the field for some years to come, though the present heavy cost of mining tells greatly against the profitable working of the lower grade ores. Chutes of quartz, and of ore in the quartz, must be always liable to thin out both in length and depth, but may be expected to make again, but not necessarily in the same plane, hence the importance of crosscutting. The ferruginous formations in the banded quartzite and ironstone that accompany many of the small quartz veins may prove more generally profitable to open up than hitherto, both within the area of the map and as far south as it extends in the Dundas area, and also at Buldania, whenever battery and transit facilities are afforded those parts.

TABLE No. I.—*Analyses of Water from Norseman.*

By E. S. SIMPSON.

Geological Survey Laboratory No. ...	863A	864A	329B	636B	337B	368B	374B	Princess Royal G.M. water used for milling. Analysis by J. G. Woolcock.
Locality	Lake Cowan Trenches at Desirable G.M.	Lake Cowan Government Trenches, Norseman.	W.R. 146 (80).	G.M.L. 99 Lady Mary North.	W.R. 160, Mary Cater.	W.R. 167 (55).	W.R. 168.	
Potassium Chloride, KCl	·0513	·0738	·0105	·0101	...	·0034	·0049	...
Sodium Chloride, NaCl	10·4901	18·8806	·5427	1·0183	·5236	·1502	·4943	10 216
Magnesium Chloride, $MgCl_2$	1·5362	3·1905	·0222	·1328	...	·0262	·1368	1·964
Potassium Sulphate, K_2SO_4	...	...	...	...	·0048	...	...	...
Sodium Sulphate, $NaSO_4$	...	...	...	...	·0458	...	...	...
Magnesium Sulphate, $MgSO_4$	·3417	1·1324	·1037	·1836	...	·0267	·0527	·550
Calcium Sulphate, $CaSO_4$	·5393	·2238	...	·0825	..	...	...	·367
Sodium Bi-carbonate, $NaHCO_3$	...	...	...	...	·0603	...	...	...
Magnesium Bi-carbonate, $MgH_2(CO_3)_2$	...	...	·0505	...	·0994	·0624	·0312	...
Calcium Bi-carbonate, $CaH_2(CO_3)_2$ ...	·0150	·0124	·0593	·1106	·0173	·0361	·0730	...
Iron Bi-carbonate, $FeH_2(CO_3)_2$ ...	Trace	...	Trace	Trace	Trace	Trace	Trace	...
Sodium Nitrate, $NaNO_3$	...	...	...	Trace	...	...	...	...
Silica, SiO_2	Trace	Trace	·0052	·0072	...	·0077	·0094	...
Sodium Silicate, Na_2SiO_3	...	...	...	...	·0075	...	...	...
Alumina, Al_2O_3	·0058	·0044	Trace	·0012	Trace	Trace	Trace	...
Total Mineral Matter ...	12·9794	23·5179	·7941	1·4963	·7587	·3127	·8023	13·097

TABLE II.—*Analyses of Rocks from Norseman.*

By E. S. SIMPSON.

Geological Museum Number	5654	5438	5561	5646	5618	5455	6111	6029	6024	6119	5963	5961	5909	5650	6019	5967
Description	Dolomite.	Norite.	Norite.	Hypersthenite.	Halloysite (Mineral fat).	Felsite.	Felsite.	Porphyry.	Granite.	Dolerite.	Hornblende Mica Schist.	Biotite Schist.	Epidiorite.	Amphibolite amygdoloidal.	Metamorphic Conglomerate.	Banded Ironstone.
Specific Gravity	2·72	2·96	2·95	3·25	...	2·68	2·70	2·69	2·64	3·02	3·09	2·87	2·94	2·97	2·57	3·95
Silica, SiO_2	4·98	52·72	50·55	55·27	20·30	77·81	77·88	73·13	78·35	47·80	49·66	53·12	49·94	50·08	91·80	11·31
Carbonic Anhydride, CO_2	41·32	·04	...	...	...	...	...	·88	·19	·24	·24	·18	...	1·15	...	...
Titanic Oxide, TiO_2	·11	·61	·05	·16	...	·41	·04	·85	·18	1·23	1·43	1·16	·52	·63	1·17	...
Phosphoric Anhydride, P_2O_5	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	·06
Combined Water, H_2O	·62	·22	·36	·30	9·80	·44	·69	·28	·12	1·87	·46	1·58	·73	·91	1·04	4·55
Soda, Na_2O	·50	2·93	1·62	·86	2·36	4·18	3·16	3·52	2·86	2·54	·72	1·02	·90	1·69	·31	Trace
Potash, K_2O	·23	·65	·11	·18	·05	2·39	2·36	1·98	3·97	·60	1·40	5·75	·07	·15	·05	Trace
Magnesia, MgO	16·66	7·42	9·97	28·36	·22	·88	·62	·65	·61	7·40	5·04	6·15	9·64	7·21	·23	·33
Lime, CaO	28·00	10·94	14·77	2·93	·15	·05	Trace	2·81	·02	10·17	9·82	·63	11·23	12·60	·14	Trace
Manganese Protoxide, MnO	Trace	·30	·19	·03	Trace	·08	...	·67	·03	·40	1·53	·31	·63	·69	·27	Trace
Iron Protoxide, FeO	·92	5·53	3·40	7·17	·44	·90	...	1·68	·90	12·09	11·78	8·87	7·21	8·27	...	2·16
Iron Peroxide, Fe_2O_3	...	1·73	1·04	·45	...	...	·93	1·17	·61	1·25	3·11	3·97	...	1·21	1·06	76·31
Alumina, Al_2O_3	4·64	17·37	17·16	4·13	18·03	12·69	12·05	12·21	11·56	14·30	14·52	17·99	19·45	14·85	3·31	3·84
Pyrites { Fe	...	...	·08	·08	...	·10	·63	·09	·05	Trace	·03	·03	·02	·08	·03	·09
Pyrites { c																
Pyrites { S_2	...	...	·09	·09	...	·11	·72	·11	·06	Trace	·04	·04	·03	·09	·04	·11
Hygroscopic Water, H_2	1·73	·09	·12	·04	49·17	·09	·06	·21	·24	·44	·05	·14	·06	·13	·53	·85
	99·71	100·55	99·51	100·05	100·52	100·33	99·14	100·24	99·75	100·38	99·83	100·44	100·43	99·74	99·98	99·61

Table No. III.—*Mineral Specimens, Dundas Goldfield.*

Norseman District.

Note.—† Denotes that the specimen was collected prior to the author's visit. * Denotes that the analysis of the specimen is given on Table II.

Register Number.	Register Number of Micro-slide.	Rock.	Obtained from	Locality.
5442	...	Gypsum, powdery	Surface	Bank at edge of Lake Cowan, at the Golden Bottle, G.M.L. 112
5446	...	Do. selenite	Ditch	Water Right 93
6131	...	Do. sandy	Surface	Sand ridge, Lake Cowan, old Coolgardie Road
5613	...	Laterite	do.	Norseman-Lake View, G.M.L. 777
5967	...	Do.	do.	18 chains east of Broken Hill-Dundas, G.M.L. 240
5898	...	Travertine	do.	Near top of Mt. Norcott
5898	...	Do.	do.	Half-mile west of Mt. Norcott
779†	...	Travertine, concretionary ...	do.	Norseman
5567	...	Marine fossil shells	do.	20 chains north-east of Mineral Lease No. 1
5568	...	Do.	do.	do. do.
5569	...	Do.	do.	do. do.
5570	...	Silicified wood, eucalyptus ...	do.	Norseman-Lake View, G.M.L. 777, west boundary
5571	...	Do. do.	do.	Mary Cater S.E. Extd., G.M.L. 584, south boundary
5922	...	Do. do.	do.	Norseman-Lake View, G.M.L. 777, west boundary
5923	...	Do. do.	do.	do. do.
5657	...	Bituminous silt	Dump	Mofflin's bore, in Lake Cowan
5991	...	Auriferous kaolin ore, ferruginous	Workings ...	Ziegler's Find, G.M.L. 907, east side of banded ironstone
6122	...	Do. do. ...	do.	Quartz claim, north of Lady Millar G.M.L. 938
6123	...	Do. do. ...	do.	do. do.
3186	...	Auriferous wash	... ...	Princess Royal Deep Lead
5475	...	Kaolin pug above wash	No. 2 shaft ...	Princess Royal Prospectors' Claim, 88ft. depth
5476	...	Do. wash or cement	No. 3 shaft ...	Princess Royal Prospectors' Claim, 81ft.-91ft.
6127	...	Pisolitic kaolin	Dump	Lady May Gully, deep lead
6128	...	Do. quartz, secondary ...	do.	do. do.
778†	...	Dolomite	Surface	M.L. No. 1
5443	...	Do.	do.	About 35 chains north-east of Desirable North, G.M.L. 335

[illegible]	584	Do. do	do.	North-west side of M.L. 1
5654*	567	Do.	Pothole	10 chains north-west of M.L. 1
5579	...	Magnesite	Quarry	M.L. 1
5970	...	Do.	Surface	12 chains north-west of Nellie May, G.M.L. 873
737	...	Norite	Lower adit ...	Hardy Norseman, G.M.L. 21, in fissure
5438*	453	Do.	Surface	On road about 35 chains south-west from Trig. B/22
5439	454	Do.	do.	do. do. do.
5482	...	Do.	do.	Trig. Hill B/22, north side, 80ft. above road
5577	...	Do.	do.	Rock, near road, 19 chains west of Lake Cowan
5578	...	Do.	Dump	W.R. 167 (55), south well
5581*	596	Do.	Cliff	West side Lake Cowan, 1st point south of Causeway.
5590	...	Do. peridotite	Surface	West side Lake Cowan, between 1st and 2nd point of Causeway
5646*	565	Do. hypersthenite	do.	55 chains east from east end of Causeway
5649	605	Do.	do.	Ridge, 30 chains west of M.H.L. 19
5651	604	Do.	Well	Half mile south-west of Mt. Norcott, 20ft. depth
5652	...	Do.	Surface	North-west foot of Mt. Norcott
5653	...	Do.	do.	¾ mile west of Mt. Norcott
5891	...	Do.	do.	15 chains southerly from spec. 5577
5892	564	Do.	do.	1¼ miles west of west side Lake Cowan
5896	603	Do.	do.	North side of Mt. Norcott
5897	...	Do. coarsely crystalline ...	do.	¼ mile north of Mt. Norcott
5589	...	Epidote (?) veins	do.	west side Lake Cowan, where Coolgardie road strikes edge of lake
5647	...	Do. (?) do.	do.	55 chains east of Causeway, south boundary of norite
5932	...	Do. (?) do.	12ft. depth ...	Star G.M.L. 835, east shaft, green material on slide face
5952	...	Do. (?) do.	V.D. 70	Lady Jean, G.M.L. 757, new shaft, north drive
1988†	...	Auriferous quartz in amphibolite	... ...	Viking Norseman, G.M.L. 26, 450ft. level, assays a.u. 1·019, a.ag. 1·100
3185†	...	Auriferous quartz in banded iron-stone	... ...	Alickazander, G.M.L. 770
5454	...	Quartz reef	340ft. level ...	Princess Royal, G.M.L. 106, 340ft
5459	...	Do.	do.	do. do.
5460	...	Quartz vein in hanging wall ...	300ft. level ...	Princess Royal, G.M.L. 106, 340ft., 130ft. south from No. 7 shaft

TABLE No. III.—*Mineral Specimens, Dundas Goldfield*—continued.

NORSEMAN DISTRICT—*continued.*

Register Number.	Register Number of Micro-slide.	Rock.	Obtained from	Locality.
5461	...	Quartz reef, showing gold ...	300ft. level ...	Princess Royal, G.M.L. 106, 340ft.
5474	...	Quartz reef, barren	250ft. level ...	Princess Royal South Extended, G.M.L. 647, east drive
5597	...	Veined amphibolite with pyrites	240ft. level ...	Valkyrie, G.M.L. 831
5601	...	Iridescent quartz		Near Record, G.M.L. 901
5905	...	Quartz reef in quartzite	Dumps	Welcome Stranger, G.M.L. 585
5912	...	Vuggy quartz	Main shaft ...	Norseman No. 1 North, G.M.L. 16
5914	...	Quartz reef	North end workings	do. do.
5919	...	Siliceous sinter	Costeen	Mary Cater North Extended, G.M.L. 604
5929	586	Auriferous quartz	Underlay shaft ...	St. Patrick, G.M.L. 849
5937	...	Quartz reef	Main shaft ...	Bon Accord, G.M.L. 95
5945	590	Do. in quartzite	Dump	Agnes Venture, G.M.L. 782, central underlay shaft
5950	...	Do. sulphide ore	do.	do. do. do.
5971	...	Reef casing	Upper adit ...	Sydney Norseman, G.M.L. 20, north end. (Assay, a.u. 1dwt. per ton)
5972	...	Quartz reef and casing	No. 2 level ...	Mildura
5974	...	Do. and calcite	Lower adit ...	Hardy Norseman, G.M.L. 21, north end
5977	...	Pyrites from reef	No. 3 level ...	Cumberland, G.M.L. 579, main vertical shaft, north end
5978	...	Lode stuff	do.	Cumberland, G.M.L. 579, main vertical shaft, north end, assays 10grs. per ton
5979	...	Quartz reef	No. 1 level ...	Mt. Benson, G.M.L. 43, east reef
5981	...	Do. pay. ore	No. 2 level ...	do. Extended, G.M.L. 42, drive east
5982	...	Do. do.	do.	do. do. do. west
5983	...	Do. do.	No. 1 level ...	do. do. do. east
5988	...	Do. with carbonate of copper	Dump	Athelstone, G.M.L. 325, north shaft
5989	...	Do.	Workings ...	Ajax, G.M.L. 882, at crossing in quartz porphyry dyke

[illegible]	...	Tabular quartz on footwall side of reef	Between 80ft. and 100ft.	Northern Star, G.M.L. 821
5992	...	Quartz with mica	100ft.	Norseman No. 1 North, G.M.L. 16
5993	...	Do. with halloysite	No. 2 level ...	Mildura Norseman, G.M.L. 18
5997	...	Do.	Dump	G.G., G.M.L. 905, north shaft
5998	...	Do. showing gold	No. 1 level ...	O.K., G.M.L. 903
6016	...	Do. in ironstone, showing gold	Prospectors' shaft	Lucky Call, G.M.L. 856
6023	...	Do. do. do.	Surface	Perseverance, G.M.L. 866
6026	...	Do. pay ore	No. 3 level ...	Lady Mary North, G.M.L. 99
6027	...	Do. do.	No. 4 level ...	Lady Mary North, G.M.L. 99, winze 440ft. north of No. 7 shaft
6041	...	Do. do.	Workings ...	Queen Alexandra, G.M.L. 923
6043	...	Do. do.	80ft. level ...	Admiral Togo, G.M.L. 919, main shaft
6118	...	Do. do.	870ft. V.D. ...	Princess Royal Central, G.M.L. 840
5973	...	Do. with incrustation of asbolite	Upper adit ...	Sydney Norseman, G.M.L. 20
733†	...	Asbolite, black hydrated oxide, cobalt, and manganese	...	Princess Royal, G.M.L. 106
5618*	...	Halloysite (mineral fat)	125ft. level ...	Desirable, G.M.L. 848, south drive
6044	...	Pyrites from reef	80ft. level ...	Admiral Togo, G.M.L. 919, main shaft
6117	...	Pyriteous band 9 inches thick ...	573ft. V.D. ...	Princess Royal Central, G.M.L. 840
6126	...	Azurite encrusting ironstone ...	Surface	Lady Mary Block, Claim 1, G.M.L. 635
6573	...	Banded quarts and ironstone, lode showing gold	About 150ft. V.D.	G.M.L. 938, Lady Millar
5465	459	Opaline quartz	Surface	25 chains north-east of Desirable North, G.M.L. 335
5592	...	Do.	do.	South boundary of norite west side of Lake Cowan
736†	...	Felsite	130ft. level ...	Princess Royal South Extended, G.M.L. 647, footwall side of reef
5455*	457	Do.	340ft. level ...	Princess Royal No. 1 South, footwall 70ft. from south boundary
5481	...	Do.	Surface	Golden West, G.M.L. 650, south corner
6037	595	Do.	No. 3 bore ...	Princess Royal, G.M.L. 106, at 380ft. level
6108	...	Do.	220ft. level ...	Princess Royal, G.M.L., east reef, crosscut at 66ft.
6109	...	Do., kaolinized	220ft. level ...	Princess Royal, G.M.L., east reef end north drive
6110	...	Do.	300ft. level ...	Princess Royal No. 1 South, G.M.L. 187, 430ft. south of No. 7 shaft

TABLE NO. III.—*Mineral Specimens, Dundas Goldfield*—continued.

NORSEMAN DISTRICT—*continued.*

Register Number.	Register Number of Micro-slide.	Rock.	Obtained from.	Locality.
6111*	577	Felsite, Foliated	Between 255 and 300	Princess Royal, G.M.L. 106, near spur reef
5449	...	Quartz Porphyry	Surface	West side of hill 2 miles north from Princess Royal
5451	...	Do.	do.	East side of hill 2 miles north of Princess Royal
5463	...	Do.	do.	Mt. Barker No. 5 North, G.M.L. 109
5467	...	Do.	Cliff	Near old sports ground, Lake Cowan
5483	...	Do.	Surface	Royal Prince, G.M.L. 810, crossing west boundary.
5598	...	Do.	No. 3 level ...	Valkyrie, G.M.L. 831, hanging wall of reef south of main shaft
5599	...	Do.	240ft. level ...	Valkyrie, G.M.L. 831, end of south drive
5612	598	Do. crushed	Dump	Mt. Barker No. 6 North, G.M.L. 668
5656	...	Do. dark-coloured	Surface	Cachuanca, G.M.L. 19
5894	...	Do.	do.	Great Bonanza, G.M.L. 560, south-west corner
5895	...	Do. mineralised	do.	7 chains N.N.E. from S.E. corner of Union Jack, G.M.L. 588
5948	...	Do. black	do.	4 chains east of N.E. corner Agnes Venture, G.M.L. 781
5969	592	Do. slaty	No. 2 level ...	Mildura Norseman, G.M.L. 18
5976	...	Do. pyritous	Quarry	Cumberland, G.M.L. 579, north corner
5984	...	Do. foliated	Surface	John Bull, G.M.L. 53, east side of dyke
5600	...	Do. banded	do.	10 chains south of Q.A. 19
5943	589	Do. do.	do.	6 chains S.W. from S. corner of Lucky Hill, G.M.L. 369
5944	...	Do. do.	do.	5 chains west of N.W. corner of Golden Crown, G.M.L. 373
5946	600	Do. do.	do.	Albert Edward, G.M.L. 331, west boundary
5947	...	Do. do.	do.	8 chains west of Blue Ensign, G.M.L. 372, same dyke as 5943
5949	...	Do. do.	do.	Agnes Venture, G.M.L. 782
5968	...	Do. do.	Dump	Albert Edward, G.M.L. 331, north shaft near quartzite

[illegible]	...	Do. do.	[illegible] level ...	Cumberland East, G.M.L. 896, first dyke east of new shaft
6121	...	Do. do.	do.	Cumberland East, G.M.L. 896, second dyke east of new shaft
6031	...	Do. do.	Surface	East side of Lake Dundas, west side of M. spec. 6029
6029*	571	Porphyry	Surface	East side of Lake Dundas, two miles from Government tank
6032	607	Do.	do.	do. do. do.
6033	597	Do.	do.	do. do. do.
5940	588	Felspar porphyry	do.	Five chains east from Golden Gully, G.M.L. 328, near Lake Dundas
5591	581	Pegmatite veins	do.	West side of Lake Cowan at south boundary of norite
6035	...	Do. after aplite	do.	East side of Lake Cowan, about two miles east of Government tank
6036	...	Do. do.	do.	do. do. do.
5913	585	Granite porphyry (?)	100ft. level ...	Norseman No. 1 North, G.M.L. 16, accompanies reef
5985	594	Granite porphyry	Surface	Mt. Benson No. 1 Extended, G.M.L. 52, eastern dyke
6004	606	Do. do.	Dump	Italia, G.M.L. 165, shaft on east side
6034*	572	Granite	Surface	East side of Lake Dundas, about two miles east of Government tank
6119	578	Dolerite	No. 1 level ...	Mt Benson North, G.M.L. 42, drive east
5471	613	Diorite	250ft. level ...	Princess Royal South Extended, G.M.L. 647, main shaft, west crosscut
5480	...	Do.	Surface	Foot of hill, 19 chains northerly continuation of south side G.M.L. 335
5995	562	Do.	Near surface ...	G. G., G.M.L. 905, south of north shaft
5935	...	Do. porphyritic	No. 1 level ...	Bon Accord, G.M.L. 95, main shaft
5942	601	Mica diorite	Surface	1½ chains east of north-east corner of Belmont, G.M.L. 789
5963*	569	Hornblende mica schist, probably same dyke as last	About 100ft. ...	Bon Accord, G.M.L. 95, main shaft
5961*	568	Biotite schist, probably same dyke as last	...	1¼ chains east of north-east corner of Belmont, G.M.L. 789
5962	...	Do. weathered	Surface	do. do. do.
5440	...	Epidiorite	Dump	Moonta Norseman, G.M.L. 449
5441	455	Do.	120ft. level ...	Desirable No. 2, G.M.L. 85

TABLE No. III.—*Mineral Specimens, Dundas Goldfield*—continued.

NORSEMAN DISTRICT—*continued.*

Register Number.	Register Number of Micro-slide.	Rock.	Obtained from.	Locality.
5444	...	Epidiorite	Dump	Three Colonies, G.M.L. 88, main shaft
5588	616	Do. aphanitic	Cliff	3rd point south of Causeway, west side Lake Cowan
5999*	570	Do.	Cliff	Sunbeam, G.M.L. 157, east boundary
6024	...	Do.	Surface	1,000ft. westerly on ridge from G.M.L. 720, Lady Mary N. Central
734†	...	Amphibolite	140ft. level ..	Princess Royal, G.M.L. 106, main shaft
5448	456	Do. aphanitic	Surface	Hilltop, two miles north of Princess Royal
5450	...	Do. coarse-grained ...	do.	Eastern shoulder of hill
5462	458	Do.	About 200ft. ...	Lady Mary, G.M.L. 49, main underlay shaft
5464	...	Do.	Dump	Mildura Norseman, G.M.L. 18
5468	...	Do.	Surface	Edge of Lake Cowan, two miles N. of Princess Royal
5469	...	Do. aphanitic	do.	Near old sports ground, Lake Cowan
5470	...	Do.	do.	East side of hill, sports ground, Lake Cowan
5472	614	Do. coarse-grained ...	250ft. level ...	Princess Royal South, G.M.L. 647, crosscut east to reef
5473	...	Do.	do. do. ...	Princess Royal, G.M.L. 647, hanging wall of reef
5477	...	Do. oxidised	88ft. do. ...	Princess Royal deep lead, prospector's claim, No. 2 shaft
5478	...	Do. kaolinised	92ft. do. ...	Bed of deep lead, prospector's claim, Princess Royal
5479	...	Do. decomposed ...	Surface	13 chains east of east corner of Moonta Norseman, G.M.L. 449
5573	...	Do. aphanitic	Main shaft ...	Princess Royal North, G.M.L. 186
5574	...	Do. do.	370ft. shaft ...	do. do. do.
5575	...	Do. do.	250ft. shaft ...	do. do. do. crosscut west
5580	...	Do. hornblendic ...	Quarry	West end of Causeway across Lake Cowan
5582	...	Do. with bedding planes	Cliff	North side of island, near water lease No. 2
5583	...	Do.	do.	North side of east end
5586	...	Do. coarsely crystalline	do.	West side of Lake Cowan, point near M.H.L. 18
5587	615	Do. chloritized (?) ...	do.	2nd point south of Causeway, west side of Lake Cowan
5593	582	Do.	do.	Cliff, 40 chains west of large island
5594	...	Do.	240ft. level ...	Valkyrie, G.M.L. 831

					Valkyrie, G.M.L. 881
5598	617	Do.	...	340ft. ,,	Valkyrie, G.M.L. 881, north drive, hanging wall
5619	...	Do.	... ...	500ft. ,,	Princess Royal, G.M.L. 109
5648	...	Do.	... ...	Surface	Top of hill, south of M.H.L. 19
5650*	566	Do.	amygdaloidal ..	Cliff	West side of Lake Cowan, at 102m, 13 chains on railway
5903	...	Do.	decomposed ...	Dump	Norseman Star North, G.M.L. 398
5909	...	Do.	coarsely crystalline	Surface	Little Jim, G.M.L. 786, west side of banded quartzite
5934	...	Do.	do. ...	Dump	St. Albans, G.M.L. 55
5953	...	Do.	... ...	South-west shaft	Lady Jean, G.M.L. 757
5955	...	Do.	kaolinised	Surface	St. Albans, G.M.L. 55
5956	...	Do.	do.	do.	do. do. between banded quartzite
5959	591	Do.	... ...	do.	Five chains from south-east corner Welcome, G.M.L. 410
5975	...	Do.	... ...	No. 2 level, north end	Pride of Scotland, Norseman, G.M.L. 24
5980	593	Do.	... ...	300ft. level ...	Mt. Benson Extended, G.M.L. 42
5987	...	Do.	... ...	168ft. level ...	Rising Sun, G.M.L. 71, shaft east corner of lease
5994	602	Do.	... ...	Dump	Alice, G.M.L. 354, north shaft
6005	...	Do.	... ...	Surface	Sunbeam, G.M.L. 157, 1 chain north of south boundary
6006	...	Do.	aphanitic	do.	Norseman Prop., G.M.L. 532, north-west corner
6008	...	Do.	... ...	do.	do. do. 11 chains north of south-east corner
6010	...	Do.	aphanitic	do.	Main Ridge, 30 chains south of trig. station B/22, Woolyeanger
6011	...	Do.	do.	do.	Main Ridge, 9 chains south of trig. station B/22, Woolyeenyer
6012	...	Do.	decomposed	do.	Low part of spur north-east from trig. station B/22, Woolyeanger
6013	...	Do.	aphanitic	Upper shaft dump	About 29 chains south of south-west corner Waterloo, G.M.L. 356
6020	...	Do.	do.	Cliff at telegraph line	Five chains east of Kirkham, G.M.L. 172
6025	...	Do.	with siderite ...	Dump	Sudden Norseman, G.M.L. 44, shaft on east boundary
6038	618	Do.	aphanitic	No. 3 bore ...	Princess Royal, G.M.L. 106
6040	...	Do.	... ...	No. 1 bore ...	do. do. about 48in. bore
6112	...	Do.	mineralised	380ft. level ...	do. do. do.
6113	...	Do.	... ...	500ft. level ...	do. do. main crosscut

Register Number.	Register Number of Micro-slide.	Rock.	Obtained from	Locality.
6114	...	Amphibolite, slaty...	500-ft. level ...	Princess Royal, G.M.L. 106, 320ft. south of main shaft
6115	...	Do. mineralised ...	No. 9 bore ...	Princess Royal Extended, G.M.L. 587, after passing quartz vein
5452	...	Do. schist carbonated ...	300-ft. level ...	Princess Royal, G.M.L. 106, crosscut from main shaft
5453	...	Do. do. footwall	do. ...	do. do. do.
5457	...	Do. schist	340-ft. level ...	Princess Royal No. 1 South, G.M.L. 187, near north boundary
5576	...	Do.	250-ft. level ...	Princess Royal North, G.M.L. 186, north drive hanging wall
5585	...	Do.	Cliff	East side of island west of Water Lease, No. 2
5915	...	Do.	200-ft. level ...	Norseman No. 1 North, G.M.L. 16
6039	...	Do.	Bore No. 3 ...	Princess Royal, G.M.L. 106
735†	...	Chlorite schist, oxidised	Near surface ...	do. do.
5445	...	Do.	Dump	Three Colonies, G.M.L. 88, main shaft
5456	...	Do.	340-ft. level ...	Princess Royal No. 1 South, G.M.L. 187
5458	...	Do.	380-ft. level ...	Princess Royal, G.M.L. 106, near east boundary
5655	599	Amphibolite, actinolitic	Dump	Great Boulder, G.M.L. 104, shaft east of Q.P.
5936	587	Do. do.	do.	Bon Accord, G.M.L. 95, main shaft
6015	...	Do. do. with iron-stone bands	Surface	Lady Mary South, G.M.L. 864
6021	576	Do. do. do. ...	Adit	Lady Millar, G.M.L. 876, 4 chains from mouth
6022	...	Do. do. do. ...	Dump	Alickazander, G.M.L. 770, N.-W. shaft
6028	...	Do. do. do. ...	No. 4 level ...	Lady Mary North, G.M.L. 99, winze 440ft. north of main shaft
6042	...	Do. metamorphosed ...	Surface	4 chains east of Welcome, G.M.L. 403, top of ridge
6116	...	Do. do. ...	No. 9 bore ...	Princess Royal Extended, G.M.L. 587, at 236ft.
5996	...	Mica schist	Dump	G.G., G.M.L. 905, between Q.P.
6007	...	Mica	Surface	Norseman Prop., G.M.L. 532, east side
6014	...	Do.	Pothole	Opawa, G.M.L. 739, near south-west corner
6030	...	Do.	Surface	East side of Dundas Lake 2 miles E. of Government tank
6046	...	Graphitic schist from hanging wall	Dump	Valkyrie Extd., G.M.L. 880, shaft near N.-E. corner
6047	...	Mamilated quartz accompanying hanging wall	do.	do. do. do.
5594	...	Metamorphosed sandstone ...	Surface	Near south-east corner Mary Cater South Extended G.M.L. 534

[illegible]	...	Do. do. ...	do.	Welcome Stranger, G.M.L. 585, south-east corner
5908	...	Do. do. ...	do.	Little Jim, G.M.L. 786, east side of quartzite
				do. do. west do.
5911	...	Do. do. ...	do.	Five chains north of Little Jim No. 1 North, west side of quartzite
5916	...	Do. do. breccia	Trench	Queen of the West, G.M.L. 390, east side of quartzite
5917	...	Do. do. ...	Surface	Five chains south of Transvaal, G.M.L. 771
5918	...	Do. conglomerate ...	do.	Near north-east corner Little Jim, G.M.L. 628
5930	...	Do. do. ...	do.	Tapio, G.M.L. 550
5931	...	Do. do. mineralised	do.	do.
5938	...	Do. do. ...	do.	Belmont, G.M.L. 789. (*See* illustration.)
5954	...	Do. sandstone, kaolinised	Dump	Narracoorte, G.M.L. 161, north shaft
5964	...	Do. sandstone coloured red by oxide of iron	Surface	Near Albany Proprietary, G.M.L. 349, west side
6009	...	Do. sandstone ...	do.	Mt. Rugged, G.M.L. 562, near south-west corner
6017	575	Do. do. ...	do.	Great Eastern, G.M.L. 448, 7 chains north of
6019*	563	Do. do. ...	Open cut ...	Stella May, Q.C. 151
6129	579	Do. conglomerate ...	do.	Bon Accord G.M.L. 95, east side of main shaft
5466	...	Banded quartzite	Surface	W.R. 160, south of well
5893	...	Quartzite, green-coloured ...	do.	Welcome Stranger, G.M.L. 585, 10 chains south of
5902	...	Banded quartzite	do.	Emerald, G.M.L. 420, north end
5910	...	Do. decomposed ...	do.	6 chains north of Little Jim No. 1 North, G.M.L. 788
5920	...	Do. with opaline quartz	Costeen	Mary Cater North Extended, G.M.L. 604
5921	...	Do.	do.	do. do.
5939	...	Quartzite, green-coloured ...	Surface	22 chains east of Golden Gully, G.M.L. 328
5933	...	Opaline quartz in quartzite ...	Pothole	Vale, G.M.L. 838
5941	...	Banded quartzite with chalcedony	Adit	5½ chains east of Albany Propy., G.M.L. 349
5951	...	Do.	Surface	Golden Crown, G.M.L. 373, north-east corner
5965	...	Do.	do.	10 chains south-east of north-west corner of Welcome Stranger, G.M.L. 565
6002	...	Do.	Shaft	Pluto No. 2 North, G.M.L. 276, east corner
6003	...	Do.	do.	
6130	580	Do.	Pothole	Bon Accord, G.M.L. 95, 3ft. east of M. spec. 6129
1602*	...	Banded ironstone, auriferous ...	Workings ...	Ziegler's Find, G.M.L. 907
5906	...	Do.	Pothole	Little Jim, G.M.L. 786
5957*	...	Do.	Open cut ...	Hit or Miss, G.M.L. 863
5958	...	Do. auriferous ...	Incline shaft ...	Tarpeena, G.M.L. 192, east side
5966	...	Do.	Surface	11 chains east of Lady Bella, G.M.L. 783
6018	...	Do. with magnetite	do.	47 chains east of Morell, G.M.L. 666

TABLE No. III.—*Mineral Specimens, Dundas Goldfield*—continued.

Register Number.	Register Number of Micro-slide.	Rock.	Obtained from.	Locality.
			PENINSULA.	
6124	...	Banded quartzite with magnetite	Surface	16 chains north-east of Great Eastern, G.M.L. 448
6125	...	Do. do. do.	do.	Lady Mary Block, Claim 1, south-east corner
713†	...	Schist, decomposed, showing gold	100-ft. level ...	Day Dawn, G.M.L. 129, Central Wealth G.M.
741†	...	Slate	200-ft. level ...	do. do. do.
742†	...	Felstone, schistose	200-ft. level ...	do. do. do.
			BULDANIA GROUP.	
738†	...	Molybdenite	...	Buldania Bell, G.M.L. 779
739†	...	Hornblende schist	...	Birthday Gift, G.M.L. 736
740†	...	Lodestuff	70-ft. level ...	Northern Ajax, G.M.L. 502
5900	...	Granite	Surface ...	Buldania road, two miles west of track to Mt. Norcott
5901	...	Amphibolite, slaty... ...	do.	do. quarter mile east of last
5924	...	Quartz Porphyry	do.	Birthday Gift, G.M.L. 736, near Wooden Battery
5925	...	Amphibolite schist	Dump	Buldania Bell, G.M.L. 779, shaft top of hill
5926	...	Sulphide ore	do.	do. do. do.
5927	561	Porphyritic diorite	do.	Mia Mia, G.M.L. 676
5928	...	Casing of reef	do.	do. do.
			DUNDAS DISTRICT.	
5602	583	Granite	Surface	Noganyer Soak, Dundas
5603	...	Pegmatite vein	do.	East side of Mt. Henry, Dundas
5604	...	Mica schist	do.	do. do. adjacent to last
5605	...	Amphibolite schist	do.	East foot of Mt. Henry
5606	...	Auriferous quartz	Workings ...	Maybell, G.M.L. 4 (Mawson's Reward)
5607	...	Amphibolite	Surface	East side Mt. Henry, Dundas
5608	...	Do.	Dump	Maybell, G.M.L. 4, Dundas
5609	...	Leaf gold on quartz	do.	Gem, G.M.L. 809, Dundas
5610	...	Quartz and mica schists	Surface	Hill east side of Dundas between two quartz reefs
5611	...	Quartz with gold and copper ...	do.	Hill east side of east reef between two quartz reefs.

INDEX TO NAMES OF PLACES, MINES, REEFS, Etc.

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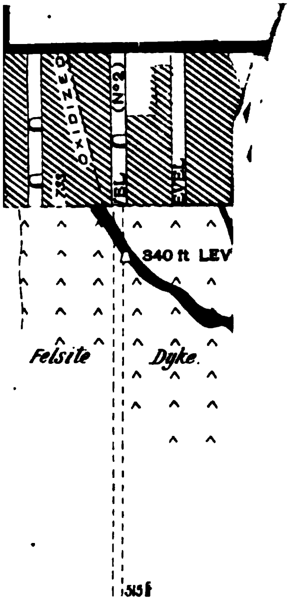
OXIDIZED
(N°2)
733
340 ft LEV
Felsite
Dyke.

683